The Future of Product Design: How Games Technology is Evolving the Design Process

A thesis submitted for the degree of Masters by Research (MbR)

by

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Declaration

Candidate's declarations:

I, Jack Gullen, hereby certify that this thesis submitted in partial fulfilment of the requirements for the award of Masters by Research (MbR), Abertay University, is wholly my own work unless otherwise referenced or acknowledged. This work has not been submitted for any other qualification at any other academic institution.

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Date…12/11/20..

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I, Iain Donald hereby certify that the candidate has fulfilled the conditions of the Resolution and Regulations appropriate for the degree of Masters by Research in Abertay University and that the candidate is qualified to submit this thesis in application for that degree.

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Abstract

The process of design has constantly evolved over the years to embrace new forms of technology that have provided numerous benefits to product designers and others in the field. This project explores how modern examples of 3D visualisation tools including Augmented Reality (AR) and Virtual Reality (VR), have been enhanced through innovations in the video game industry to combine and become powerful pieces of games technology that can help shape the future of design. Discussed throughout is a vast array of hardware and software solutions that although may have been primarily researched academically decades prior, have seen increased adoption and benefits through the addition of tools, mechanics and processes commonly found within the games industry. Various methods were undertaken to research past and present work in the field including the analysis of existing solutions, as well as the development of new technological applications. Four case studies explored games technology in the world today and the many ways in which it can be repurposed for use outside of entertainment. These case studies, combined with prototyping carried out using games technology for experimental purposes, provided insight into how best to develop two applications for evolving product design (*Reality Works* and the *VR Camera Tool*). Once these were developed, they were evaluated in terms of their usability and fitness for purpose. Two test sessions featuring a total of thirty participants provided feedback on both applications. The results were largely positive, indicating that the software did stand to benefit design and provide new processes for product designers. The results also highlighted the need for clear and concise tutorial systems when introducing new solutions to participants. Whilst there is further work to be done in the form of User Interface (UI) research and additional software development, test participants indicated that designing using the games technology utilised was easier, faster and likely to be useful going forward. This research evidences that games technology, particularly that which encompasses AR and VR, has a place outside of the entertainment world and can help shape the future of design.

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1 Introduction

Design as a discipline is constantly evolving. In the past decade this has shifted from mostly physical to predominantly digital design. The possibilities for adopting new technology as part of this process have greatly increased. In 2020, designers can be at opposite sides of the world and still collaborate within a shared 3D environment. This is in part thanks to games technology. Game engines have provided an easy way of manipulating 2D and 3D content and adding custom interactions for the user. With the knowledge of how to use these tools, the design process can be customised however the user would like, opening up vast opportunities for innovation.

There has been a wide variety of technological advances in the past several decades which have been responsible for advances in design. Often these advancements have been researched for years in isolation, with 3D visualisation tools such as Augmented Reality (AR) and Virtual Reality (VR) being a prime example. In recent years however, modern interpretations of AR and VR have utilised approaches and toolsets common in the world of video game development and this has led to new opportunities for integrating them into the design world. Now AR and VR solutions developed with a game engine have the potential to produce new examples of games technology, that could serve many purposes.

With the introduction of AR and VR into the design landscape, we may once again see a significant shift in how designs are conceptualised, generated and further developed. Ideas from video games developed in the 1990s potentially assisted in improvements to the user experience design, with similar menus and interactions making their way into modern application interfaces (Brandall, 2016). AR and VR have the chance to make a similar impact.

The research included in this project looks to present possible methods of evolving design, with a focus on AR and VR. To do this, a close study must be taken into how the design process has evolved. Due to the nature of the project, the product design pipeline will be explored. Whilst the research carried out focuses on product design in general, the project will be influenced by the various pieces of work contributed to through the product design consultancy that supported this research, Seymourpowell. Throughout the course of this MbR project, the researcher has worked in a joint role of academic researcher, and a Creative Technologist at Seymourpowell. Seymourpowell have a direct interest in learning more about the use of games technology in product design, having explored its use in the past. They therefore encouraged this academic research to bring new solutions to the field of product design.

Seymourpowell have been a product design agency for over thirty-five years working on a huge spectrum of product categories. Their 35 year back catalogue includes projects in the automotive sector, rail, aerospace, consumer electronics, structural packaging, medical and various other fields. The work carried out for this project will help further understand how the addition of new technologies such as AR and VR can assist and improve the design process across all of these areas.

The direct access to the work at the company has provided enormous benefit to this research, allowing for increased insight into high level product design projects within industry. Working with their level of experience has also allowed for an array of information and expertise to influence this project.

The members of Seymourpowell are a collection of expert problem solvers with a wide range of backgrounds, specialisms and skillsets. A key interest to this research project was the understanding of the process and pipelines in place to ensure new products are designed successfully. A typical pipeline for creating a new product at Seymourpowell would involve identifying a client’s needs and wants before designers would then begin developing concepts. Throughout this process there would also be input from the foresight team to ensure the design met certain criteria if a specific market was being targeted. In accordance with the client, a Colour, Material and Finish (CMF) style would also be agreed and then applied as part of the design as well as branding (if included in the original brief). These processes are integral to the creation of new products at the company and any disruption to this methodology must be carefully planned and thought out. Despite this, experimenting with new technology is a common part of development at Seymourpowell and in the product design industry as a whole. Product design as an industry has always looked to embrace technology and now more than ever it has the chance to upkeep this tradition.

There are already examples in this field of new devices beginning to make their impact. NASA, Volvo, and Lowe's are all experimenting with using Microsoft's HoloLens, an AR or "Mixed Reality" headset, in their design process (Taylor, 2016). Car manufacturer Ford is actively using the device as part of their design process, allowing them to work collaboratively with designers and engineers from around the world. (Schneider, 2018). The HoloLens allows designs to be viewed virtually in front of the designer at full scale, providing them the opportunity to walk around a design that is yet to exist (Microsoft, 2019a). In addition, the technology is fully wireless. Designers can step outside and visualise their ideas in the real world, without being tethered to a computer, a step forward for automotive design. Makers of the game engine *Unity* also recently held their first ever AutoTech summit in Berlin. Here they described how their game engine can allow professionals in this industry to begin "building, visualizing and sharing their interactive 3D designs and immersive experiences in diverse applications" (Unity Technologies, 2019a).

Games technology has influenced the way in which we design, with AR and VR being a key next step in evolving the design process. The research question points to the overall goal of this project which will be to discover ways in which the product design landscape can benefit from the uptake of such technology.

1.1 Research Question

The aim of this research is discussed below. Framing this as a research question would read as follows: The Future of Product Design: How Can Games Technology Evolve the Design Process?

1.2 Aim

The overall research aim is to explore the current practices in use throughout the product design pipeline and understand how these could be further enhanced using games technology. By researching and observing various pieces of work in the field, an understanding will be built of the context in which designers in this field develop their products. By discovering the ins and outs of this process, the goal is to then create new tools using technology available to assist designers in the future of their work.

1.3 Objectives

i. Explore the impact that games technology has on the design process.
ii. Develop various products in which games technology assists design.
iii. Investigate how AR and VR can impact the future of the product design pipeline.

1.4 Background

Interest in this area began through previous projects investigating potential use cases for AR and VR technology, with industries researched including:

- Architecture
- Construction
- Data Visualisation
- Education
- Engineering
- Healthcare
- Law Enforcement
- Training
- Travel

One industry in this background research that was given greater focus than the rest was the aviation industry, specifically Air Traffic Control (ATC). Prior to the research discussed into the field of product design, a prototype was developed exploring how the ATC landscape of the future could rely on AR and VR. The methodology involved in this past research of studying existing practices, before designing and testing new potential solutions, will largely influence the investigation into how the same technology could shape the next evolution of product design.

AR and VR are two technologies that were of particular interest to the researcher. Other previous projects have explored the benefits in combining these technologies of AR and VR, exploring how they can change everyday life, trying to improve on a standard computer setup for design and taking less common games hardware and reusing it to create beneficial product solutions. As well as a primary focus on AR and VR in the past, over five years of research into common games technology such as game engines and custom input methods have been carried out, again influencing this research.

This background knowledge has only furthered interest and led to this research, exploring more ways in which games technology, including AR and VR, can completely revolutionise the world of design.

1.5 Thesis Structure

The Research Contributions chapter identifies the areas this research looked to evolve, before any development or evaluations took place. The content of this chapter outlines ways in which the research planned supports the product design community and the impacts it could have on the profession.

The Literature Review examines critical developments in the traditional design process, including commonly used practices within the world of product design. The chapter then details existing aspects of games technology and how these can impact the product design world.

The Case Study Analysis chapter outlines the findings of several case studies that were undertaken to provide insight into the development of *Reality Works* and the *VR Camera Tool*. These case studies explored games technology and 3D visualisation technology already used in the field of product design and the methods in which it proved useful.

The Research Methodology chapter examines the process used to carry out the investigative research. This was primarily through the development of prototype software, or in the form of case studies further exploring technology within design. The software developed and utilised were various tools that used AR, VR or other games technology outlined over the course of this research.

The Results chapter dissects the questionnaire analysis carried out on the prototype software created and examines user responses to testing, with the key takeaways being presented.

The Discussion chapter explores the impact of the results captured. By further analysing the research carried out this chapter suggests definitive ways in which games technology can more greatly benefit product designers.

The Conclusion chapter recaps the research carried out and details the outcomes of this research. It also outlines the current state of games technology in the product design industries and predicts how this could change in future.

The Future Work chapter explores the possibility of additional research and work to be carried out based on the results obtained through the research project in order to obtain further analysis.

1.6 Research Contributions

This research study explores the use of games technology in the field of product design and design in general. Past examples of companies and individuals attempting to introduce technology to shape the design process have been studied in order to obtain an insight in how these succeeded or failed. Focus was given to investigate ways in which designers could benefit from future facing workflows. These were built within a game engine, allowing functionality to be discovered and developed that has the potential to improve on current practices.

The aim of this project is to explore the impact of technological advancements on the design landscape. This was explored through the creation of various applications.

Before the primary applications of the research project were undertaken (*Reality Works* and the *VR Camera Tool*), experimental prototyping was carried out to establish the best methods for integrating and using AR and VR to benefit design. This prototyping process was integral to the development process as it informed all further work. Prototyping continued throughout the development of *Reality Works* and the *VR Camera Tool* to continuously investigate new ideas and concepts.

Reality Works was a key aspect of this research project and involved investigating the best way to collaborate on various types of design using VR technology. Seymourpowell's *Reality Works* was enhanced with the intention of further integrating it into the product design pipeline. The software and its features were utilised in a variety of different projects at Seymourpowell, benefiting the design process for each project. These benefits were determined after designers found it easier to review work together inside VR and various projects were able to have far more iterations on designs than before VR processes were used. The *VR Camera Tool* was another key aspect of this research that was also used in various projects and provided a further in-depth investigation into how games technology can assist design.

These technologies and the new functionalities they explored could serve as the basis for further research into games technology being applied to the field of product design. The quantitative and qualitative analysis, as well as the case studies discussed below, provide further insight into the contributions these developments have made and could continue to make on the world of product design.

To ensure an AR/VR design experience was beneficial, the key usability metrics were analysed to determine the speed in which the application could be used as well as how interactive it was whilst still providing high quality information. All applications developed had to integrate into pre-existing workflows and be as adaptable as current design software is. The key characteristics focused upon were those that brought the greatest benefits to designers.

From 2016 onwards, there have been numerous examples, some of which have been discussed, of how the world of design is changing. By allowing more time to be dedicated to research in a field that is typically business focused, this project has the added value of being able to potentially redefine the product design pipeline. As well as this, new methods of design could emerge from further implementations of the research carried out.

2 Literature/Contextual Review

Product design encompasses many different skillsets, backgrounds and input from a variety of disciplines. Effective product design can be carried out in a range of different ways but in 2020 this often makes use of recent technological advancements. The evolution of product design is an ongoing process and one that is being driven partly by games technology. Other evolutions in computer processing power and the reduction in cost of hardware are also driving this change, but these are outside the scope of this research.

The term ‘games technology’ will be referred to throughout this project as a term used to describe hardware and software solutions that are today utilised in the world of video games but may also have applications far beyond this field. Historically, many of the technologies discussed were developed in separate industries from that of games but the advances that video games have provided these technologies has led to their growth and increased use. AR and VR for example are 3D visualisation technologies that have been utilised in many areas for decades, examples of which will be discussed throughout. However, it is the modern era of AR and VR that this research intends to focus on. This past decade has seen many use cases for AR and VR in the world of design and other industries, many of which have been made possible thanks to the functionality found in the most recent game engines. Today, many AR and VR experiences are produced using the exact same tools as those used to develop video games. Games technology has therefore brought powerful new mechanics, workflows and interfaces to such innovations, whilst also reducing cost and making it easier for new design solutions to be developed.

Games technology has often spilled over into other fields including product design, for example researchers have discovered that the Nintendo Wii remote is incredibly accurate at gesture recognition, and also makes it possible for “literally anyone to build and explore 3D spatial interfaces” (Keefe and LaViola, 2011). Relevant applications where games technology enters the world of design will be explored in this research. Input devices that feature different control methods and various forms of interaction will be key areas of focus, as well as new and existing mechanics, particularly in the devices closely explored such as AR and VR.

2.1 The Traditional Design Process

The traditional design process from the early 1900s has involved refining and evolving an idea. Goffin and Micheli (2010) describe how the development of new products requires a concept created from consumer needs, before it is designed further and turned into a physical product. Tayal (2013) agrees with this reasoning, arguing the design process encapsulates various brainstorming methods, idea generation and prototype building before a physical product will materialise. Once this process is complete, it is typically repeated until the final design is agreed upon. This project's focus is on how technology is assisting and adapting this process. Don Norman (2013, p. 34) notes that whilst "design requires great designers", it also requires much more including a "number of different disciplines" to reach the final product. Whilst consulting hundreds of people can help get a varied spectrum of opinions and a greater input of skills, there is a risk of a 'too many cooks' scenario where the consultation of an increased number of designers could potentially be detrimental to the project as a whole. Research has shown that when combining various teams to work on innovative projects, projects with higher numbers of teams involved often produce less successful results (Baier, Gemünden, and Rese, 2013). To minimise delays and avoid confusion, designers need tools to communicate their designs easily and clearly. Tools such as *Adobe XD* (Adobe, 2016) have provided platforms that enable this, "allowing designers to build and update intricate designs with ease" (Valishvili, 2018).

Blending tools and technology into the world of design has been a concept for over a century. In 1919, The Bauhaus in Germany was established, which became a world-renowned centre for the development of design (Weber, 2019). It was here that architect Walter Gropius determined that the Bauhaus would be responsible for bringing technology together with design, sporting the motto: “Technology might not need art, but art certainly needed technology” (Bürdek, 2005, p. 28).

Figure 1. Barcelona Chair by Reich and Rohe (Knoll, 2019)

Figure 2. Wardrobe on Rollers by Josef Pohl (Juan, 2019)

The Bauhaus spawned various world-renowned designs, many of which still shape our lives today. Some notable examples include: the Barcelona Chair (Figure 1) by Ludwig Mies van der Rohe which was first unveiled in 1929 and has become a commonplace design utilised around the world (Poon, 2017). Another is the Wardrobe on Rollers (Figure 2) created by Josef Pohl (Hitti, 2018). Whilst simply a standard wardrobe placed on wheels, this thought process allowed it to become “known as the ‘Bachelor’s Wardrobe’ due to its mobile and space-saving qualities.” The wardrobe provided a simplistic design with enough innovation for households at the time. Finally, the Door Handle (Figure 3) by Walter Gropius is one of the most recognisable products to come from the

Figure 3. Door Handle by Walter Gropius (Tecnoline, 2010)

Bauhaus, conceived in 1923 and a design still replicated to this day (Tecnoline, 2016).

All of these products follow the core principles set out by the Bauhaus such as “form follow[ing] function” and the “unification of art and technology” (Edwards, 2019). The appeal of the Bauhaus style of design and why it is so world-renowned is the fact that everything is done with a purpose rather than simply to look aesthetically pleasing. These products also solved a problem, much like the integration of games software into design should aspire to do. By taking inspiration from the Bauhaus philosophy of fusing art and technology, devices such as VR headsets provide a potential evolution in design thinking, possibly helping shape products of the future. Design thinking refers to the process that gives designers the drive to “experiment, create and prototype…gather feedback, and redesign” (Razzouck and Shute, 2012). Whilst technological advances present change, the ones discussed in this project still follow the underlying design principles taught by the Bauhaus and others.

To comply and follow some of the leading product design thinking of the past, the research carried out in this project aspired to apply the design thinking that made the Bauhaus a success around a century prior. Every tool developed, feature integrated or even prototype considered was done for a reason. The Bauhaus tackled problems and designed with a purpose in mind, which this research has also aimed to achieve.

Design is not focused on aesthetics alone; it largely considers the use case of a product. When creating a design, we need to determine how it will be used, asking ourselves questions such as “what do I want to accomplish?” and “what action can I do?” (Norman, 2013, p. 71). By following these a customer will not have to figure out how a product can be helpful, instead this “puts the burden on the designer” to ensure at every stage their creation is customer focused.

Getting the most out of our designs is based around seven key principles according to Norman (2013, p. 72):

1. Discoverability – being able to determine what a device can do.
2. Feedback – easy to determine what action has been carried out.
3. Conceptual Model – the design projects all information of the system required.
4. Affordances – the proper affordances exist to make actions possible.
5. Signifiers – signifiers to determine actions and feedback are present.
6. Mappings – controls are clear and in a straight-forward manner.
7. Constraints – logical limits are provided.

If we take a typical chair for example, it meets the above criteria. People are aware of what it does and can easily use one. Unless it has been designed poorly almost all will understand what the product is, and the affordances convey that users can sit on it. Whilst its constraints may be slightly less obvious, logic dictates how and how not to use a chair.

Famed German industrial designer Dieter Rams, who helped spawn many of Braun's consumer products over the years, developed his own set of principles that agree in several aspects with Norman's approach to design. His approach of making products that were "useful", "understandable" and containing "as little design as possible" (McCormick and Spee, 2012) showcase that design is not about making an incredibly complex and world changing solution. Whilst it can still be these things, design must be straight forward to use and only contain the absolute necessary.

In contrast, Bürdek (2005, p. 16) notes that the concept of design can no longer be "uniform" and "cemented" as one central idea. Well into the 1980s "there was no problem with such an open description of design". In the 21st century however, design encompasses so many aspects of modern-day life that it is difficult to pinpoint one specific method for success. Therefore, Bürdek has "[listed] a number of the tasks design is supposed to fill" including:

- Visualising technological progress.
- Simplify or enable the use of hardware or software.

- Highlight the connections between production, consumption and recycling.
- Promote and communicate services whilst preventing senseless products.

An increase in awareness around climate change has also presented a design shift. Designs need to be more technologically minded whilst remaining focused on sustainability for the planet. Berawi (2015) focused on this when discussing how “technology innovation [will become] an important instrument to increase the flow of new ideas and next-generation products”. He went on to explain that using such innovation allows for a competitive edge and the production of “improved products”. The key message here being that technology’s use in modern design will benefit the generation of ideas. This agrees with Hurt (2011) who explains the use of an innovation “Permacane” which has allowed for the material Rattan to be used as an eco-friendly building material. Using this material, new buildings are constructed, with more sustainable and renewable natural resources being an important part of the process.

Design has often driven change and embraced state of the art developments. In the past ten years however, advances in technology have taken place as a separate entity from the design world. Whilst the methods of the Bauhaus of form following function still apply, these new solutions must be embraced to ensure the design process does not fall behind the times. Although this brings about change that is arguably for the better, it must be done robustly to ensure the design methods of the future adhere to their own correct principles.

Design is always evolving, and with this product design as an industry may change. As we have seen, in the advancement of design, new techniques are utilised, new technology evolves, and new ethics could have to be adhered to. All that remains is for the methods to be discovered.

2.2 Evolving Product Design

Previously, the product design process often began with paper sketches that were discussed as concepts for a finished product (Green, McGown and

Rodgers, 2000). Sketches would be refined, turned into physical models and iterated upon until the final design was agreed. Nowadays this pipeline is still followed to an extent, with the addition of computers now making this process much faster and easier. The introduction of Computer-Aided Design (CAD) software was a revolution for the industry (Richards, 1985).

CAD allows designers to build products entirely on a PC or laptop. What would previously be the results of many diagrams and drawings can be created as a digital file. CAD has catalysed a digital revolution for the product design world, reducing the need for physical prototyping and speeding up processes. Changes to designs do not require starting a detailed drawing again, they can be made quickly by editing a file. CAD software has been around since the 1960s (Fucci, 2011, p. 3) but took several years before it was able to move from 2D to 3D development. In 1983, *AutoCAD* was released in what became a monumental shift for the use of CAD by designers. It provided a more cost-effective solution to carrying out design using a PC. *AutoCAD* is still in use today, with creators Autodesk still an industry leader in CAD software (Autodesk, 2020). CAD software provides many benefits, aside from digitising the design process, some of the most notable benefits include (Schilling, 1986):

- Increased quality of documents
- Increased speed with which they are completed
- Increased number of design alternatives generated

With these vast benefits, the overwhelming majority of projects today fully utilise CAD as part of their pipeline, allowing for greater productivity and enhanced workflows. CAD is also used in other industries including architecture and engineering. In 2012, CAD was voted by industry figures and readers of Architect’s journal as the greatest advance in construction history (Architect’s Journal, 2012).

CAD has now been adopted worldwide by over nineteen million users, helping to shape product design as we know it, and is considered the cornerstone of modern design (Livingston, 2012).

In a guide published by leading software firm Adobe, Nick Babich (2018) describes a common pipeline for product design in 2018:

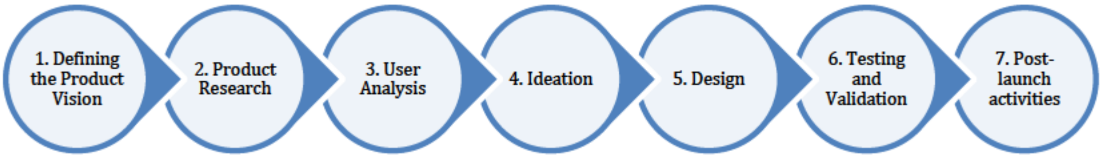

Figure 4. Common Product Design Pipeline

This entire process involves scoping out the project and researching the needs of a client, to then looking at the end users of a product and understanding their use cases. Once this has been carried out the product can be conceptualised, iterated upon and eventually released after being tested to ensure the product is fit for purpose.

"Product design is more than simply creating a physical or digital object. It is about the tasks people accomplish with the help of the products that are designed and built and the experiences they have while doing so." - (Jing, 2018, p. 27)

Analysing the above, product design is about problem solving and responding to the challenges we face in everyday life. "During the design procedure, the designer should transform customer requirement[s] into the required product" (Chen, 2009). The key focus for those in this industry is therefore providing a quality service to consumers through the creation of a product that fits their needs. A car gets people from A to B, a bus also does this but for a larger group of people. Each providing a solution to a problem. Product design stems from solving these problems by breaking them down into several phases.

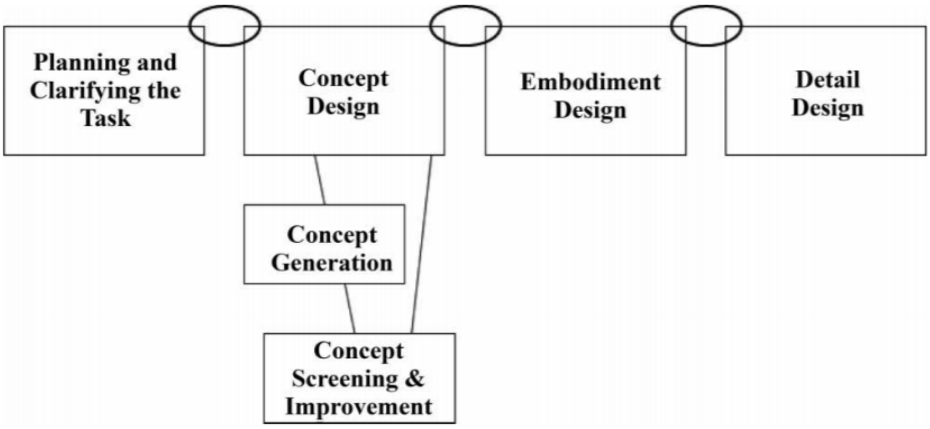

Figure 5. Phases of Product Design (Adler et al., 2007)

These phases tie in with the common pipeline discussed earlier. The product design process is about setting boundaries and defining an idea from the get-go and then working detail and research into this. By following this process designers go from discovering “a product idea that is needed” to “all the individual parts [being] finally determined” (Adler *et al.,* 2007).

Product design processes have continued to evolve with digital trends over the years. Embracing technology has proven key in expanding skillsets and opening up new opportunities for design. In 1984, Wacom released their first graphics tablet. This was positioned as a device for CAD users to draft drawings with and from here Wacom quickly became a leader in the world of graphics tablets (Smith, 2017). Technology such as this has made it easier to make the leap from sketchpad to digital PC.

Another evolution that has benefitted designers is the introduction of cloud hosted files. These are collaborative files that can be worked on by multiple people at the same time. At a basic level they are simply word-processed documents, but even presentations and statistical data can now be worked on in unison. Popular examples include *Google Docs* (Google, 2006) which has allowed for collaborative document creation for over a decade, and in 2016, Apple introduced real-time collaboration to their suite of applications including *Pages*, *Numbers,* and *Keynote*. This allowed multiple users to plan, create and develop together (Kahn, 2016). Cloud collaboration has become a key element in allowing designers to work together across the globe and is likely to be utilised even further in the future.

Finally, 3D printing has been a recent technical advancement for the design world, offering up the ability to create mock-ups or components at a faster rate. With 3D printers available for less than one thousand dollars (3DInsider, 2017) it is an item of technology that businesses are quicker to adopt these days. According to Bangert (2017), 3D printing opens new possibilities as designers can "bend the rules" that traditional manufacturing has forced them to obey. With this technology providing a new platform for manufacturing products, materials and designs can now be experimented with more as the tools of manufacture come with fewer caveats and restrictions.

We can see that there is room for product design to grow with technology. Games technology is already present in the field and being used day in day out by companies such as Seymourpowell. Applications such as *Procreate* (Savage Interactive, 2011) and *Shapr3D* (Shapr3D, 2016) have made it easy to sketch concepts and design products with evolving hardware such as the Apple Pencil. In the past two decades, developments from the games industry have helped take product design to new heights.

2.3 Games Technology in Product Design

Digital devices have had an impact on product design since their inception. Prior to the influence of the games industry, there were many digital advancements that propelled the product design industry towards what it is today. Douglas Engelbart, inventor of the mouse, developed a two-handed input method as a prototype for digital design (Popoff-Walker, 2017). This is one of the early examples of digital technologies making their way into a previously established medium. Engelbart could be considered one of the key contributors to the modern digital world. In 1968 his "mother of all demos" showcased "word processing, document sharing, version control and hyperlinks, and he'd integrated text, graphics and video conferencing" (Landau, 2018). All of these are useful digital developments we take for granted on a daily basis. As computers and digital applications have become more prevalent, there are even more control methods for assisting product design. Since 2015, the application *Onshape* (Onshape, 2015), which is utilised by thousands worldwide (Cooke, 2020), has provided a new use for cloud technology. It allows designers to work collaboratively on the same file whether they are on a PC or a mobile device. Designs can be iterated on simultaneously, without the need for a designer to save the file to a shared access point before another designer can take over. CAD models are able to be updated from anywhere in the world by using touch input to customise designs on the go. In the past it would have been necessary to have a large amount of desk space in order to fully design a product. At present, companies and designers can make changes regardless of location or scenario, with all of the information being stored for the rest of the team to give input on. Touchscreen devices have become common input methods used ever since the first iPhone was released in 2007 (Apple, 2007), and this has led to many enterprise applications now seeing the value of personal devices being used in an individual's working life.

2.3.1 The Introduction of AR and VR

AR and VR have quickly become the latest advancement in technology that have the potential to provide changes to our working lives. Whilst having a renewed interest in the past ten years, the technology was first developed over fifty years ago. In 1968 Ivan Sutherland and his student Bob Sproull developed the first head mounted display (HMD) used to visualise 3D content. It featured the ability to inspect a wireframe model from various angles, a technical revolution at the time (Steinicke, 2016). Other past developments include the VITAL helmet from the McDonnell Douglas Corporation which visualised scenarios for fighter pilots and was used alongside head tracking technology to respond to user movement (Coblitz and MacLeod, 1979). NASA has also been experimenting with VR displays since 1989, as they provided safe access to simulations that represented working in micro-gravity (Hale, 1995). Work in aerospace and aircraft design is one of the earliest industries to adopt AR and VR. In 1992, Thomas Caudell and David Mizell from Boeing developed one of the first AR devices. They describe it as a see-through headset that allows "a computer-produced diagram to be superimposed and stabilized on a specific position" (Caudell and Mizell, 1992). The main use case for this early development of AR was to overlay useful information as part of the aircraft manufacturing process, making it easier for workers to assemble an aircraft. A technique still relevant today, almost thirty years later. Also developed in 1992, Louis Rosenberg's *Virtual Fixtures* was an AR system that overlayed information to make it easier to perform tasks in remote environments. The system utilised an exoskeleton to track the user's arms and provided sensory feedback to the user. It was found that the additional feedback the AR system provided allowed for "increased operator performance [of] up to 70%" when performing a standard task (Rosenberg, 1992). There have been decades of research into AR and VR solutions. Sutherland's work and the developments that followed have since inspired technical innovation allowing AR and VR to progress to what we know it as today. In 2013, Oculus released their first developer kit, commonly referred to as the DK 1, and this modern era of VR research began (Schleußinger, 2021).

Modern AR and VR devices have a large backing and have the potential to take over our lives given the correct investment. Tech giants including Google and Alibaba have helped raise over $2 billion for AR start-up Magic Leap (Meyer, 2017), although they suffered dozens of layoffs in 2019 due to poor hardware sales (Valentine, 2019), a sign that the technology was still immature. VR has also been invested in heavily. Global technology giant Facebook acquired Oculus in 2014 for $2 billion (Facebook, 2014). In terms of hardware sales, two of the leading VR headsets, the *HTC Vive* and *Oculus Rift* had sold approximately 663,000 units combined by the end of 2016 (Ergürel, 2017). This equates to almost ten percent of the combined sales of the *PlayStation 4* and *Xbox One* which were approximately 7.2 million units in their launch year (CBS News, 2014). Almost ten percent in comparison to an already established piece of games hardware is impressive when considering these VR headsets also required an additional PC to run them.

VR technology has made what was previously expensive, time-consuming or in some cases physically impossible, readily achievable. By placing a VR device onto their head, a user is fully immersed in a different environment. They are able to walk around this space freely and, if part of the experience, interact with the elements of the digital world. This helps product designers communicate their vision, placing people in environments where designs can be fully appreciated thanks to no outside distractions.

Headset-based devices have the potential to change many current practices, with a range of possibilities being easy to imagine. Architects can view their building plans in 3D space, literally walking under door frames to ensure they are the correct size. Apartment showrooms and hotels that are thousands of miles away can be presented to the customer from the comfort of their own living room. Since 2017, *Open House VR* has made this possible through a downloadable app (HTML Fusion, 2016). Designers can use examples such as this to enhance their current workflows. The fact that you can now bring people into 3D space internationally greatly enhances collaboration. Researcher Elizabeth Gerber (2007) noted that creative collaboration was one of the key principles of improvising design. “Group drawing” is one such method she discussed that supports this. It allows multiple people to have their say on the design process. By doing this whilst viewing a digital representation of a final product, it allows designers to notice any required changes more easily.

Since 2018, VR in particular has been embraced by countless industries: healthcare, education, entertainment, sports and many more (CB Insights, 2018). When we look at these examples the understanding as to why this particular interaction method has been embraced is because it provides a step up from a desktop PC, by making the impossible, possible. The advancement in simulation and immersion is vastly improved through the usage of VR technology.

AR is expected to follow a similar path to success with an increase in adoption rates anticipated in the coming years. It is expected that by 2023, over 2.4 billion people will make use of AR through their smartphones (See Figure 6). This will be achieved via AR apps available on mobile app stores and web-based AR content accessed through the device’s browser, with AR experiences such as online shopping and marketing experiences being just some of the types of AR content available.

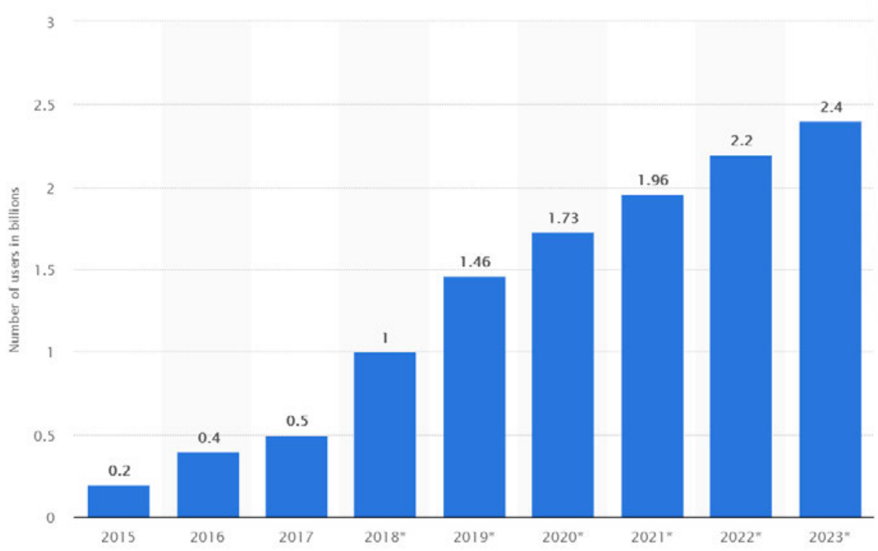

*Figure 6. Mobile AR Users Worldwide from 2015 – 2023 in Billions (Statista Research Department, 2020) *Forecast*

As can be seen from Figure 6, this is exponential growth in only a matter of years, an enormous growth rate of 1200% that suggests the technology will continue to influence the habits of individuals when using the technology. Whilst VR headsets are expected to dominate unit sales, in 2017 it was predicted that AR will dwarf VR in terms of revenue by 2021 (See Figure 7).

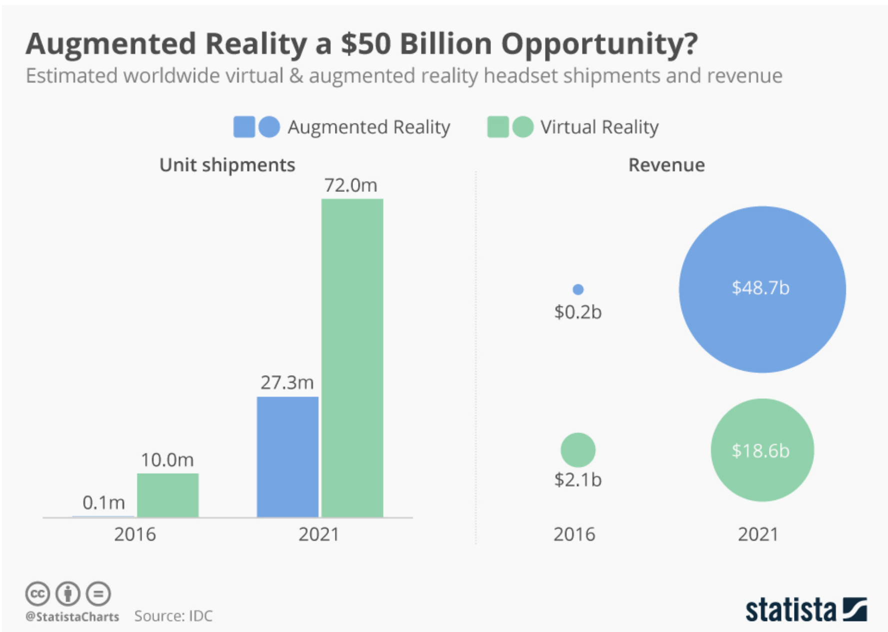

Figure 7. Potential Growth of AR & VR by 2021 (Richter, 2017).

There are several reasons that this could be believed. You can assert that due to the almost universal usage of mobile phone technology, there already exists an AR capable device in people's hands. VR on the other hand requires an additional hardware kit, or possibly AR is more appealing to brands as they can place their content in amongst the real world instead of an isolated experience. The use of mobile AR also removes the need to wear cumbersome headsets and a report from 2017 found that people are often "glued to [their] smartphones" (Deloitte, 2017). The report also highlighted that millions of the public use their phone whilst walking or even crossing the road. The mobile AR audience is easier to capture if millions are always connected. The growth of both AR and VR platforms is exciting for product designers, and this growth will require increased input and development going forward.

Despite the increased potential of AR and VR, previous research has outlined various factors that developers and designers alike have to be cautious of as these devices become more common place. One main factor is that not everyone will want to use AR or VR and there may be some resistance to change. Solutions have to improve over what already exists and make designers feel they are benefiting from the use of the technology. Therapists studying the effects of VR for mental health analysis found that the number one barrier to implementation was that "a VR application might not fit or complement their current way of working" (Bouman *et al.,* 2019). A similar result was observed by Roose (2020) who theorised that because humans are "creatures of habit…it may be that people simply prefer virtual experiences that don't require them to strap an expensive computer to their forehead". If people see no advantage to the technology, then it is not fit to improve upon an existing process. In spite of there being possible reluctance to the adoption by some, games technology is frequently making painstaking processes of the past easier, a good way to win over the minds of sceptics.

2.3.2 Engines That Drive Change

AR and VR applications are typically constructed using game engines. For example, *HoloMaps* (Taqtile, 2016), an AR application that overlays real-time information on top of building models was built using a game engine. A game engine is a piece of software that provides a way for games software to be created for users' devices. One of the main engines used as part of this research is the *Unity* game engine (Unity Technologies, 2018). Despite being considered a games platform, *Unity* is able to be used to construct common software, something they have embraced in recent years. *Unity* and its main competitor game engine, *Unreal Engine* (Epic Games, 2020) have both shown increased interest in supporting the use of their engines as design tools. *Unity* recently held their AutoTech summit which brought together some of the world's largest car manufacturers to discuss how the platform enhanced their workflow (Unity Technologies, 2019a), and Unreal Engine recently revealed their product *Unreal Studio* which aims to provide a suite of tools that "accelerate [the] enterprise workflow with Unreal Engine" for free (Epic Games, 2018).

With *Unity*, almost any type of input (mouse, keyboard, touchscreens, VR controllers) can function using the system, with developers choosing how to utilise the engine. In terms of new input types, *Unity* has recently adopted the functionality to support multiple XR (Cross-Reality) devices (Unity Technologies, 2019b). This encompasses AR, VR and Mixed Reality (MR) headsets. By providing this support it is allowing a common platform to be developed, where software engineers focus on the content output rather than the hardware required to run it. Similar to how Windows and Mac platforms can share files, despite running different Operating Systems (Schofield, 2014).

In 2018, headset manufacturers have gone a step further with the three major platforms (HTC/Valve, Oculus and Microsoft) all making their hardware able to run on the Steam VR platform (Chacos and Newman, 2018). All three have also agreed to use the new VirtualLink standard, a dedicated port connected to the motherboard, for connecting headset to PCs allowing ease of access for users in the future (VirtualLink, 2018). It was developed by an industry consortium led by NVIDIA, Oculus, Valve, AMD, and Microsoft, many of the major players in the VR world and can be described as the VR equivalent of all TV devices connecting via HDMI. Oculus recently took their support a step further and followed HTC/Valve in allowing software developed for Oculus devices to run on the HTC Vive hardware out of the box as shown in Figure 8. Whether the developer started off creating a VR app for Oculus or HTC Vive, the app created will now work on both, allowing developers to choose to work on the platform they prefer.

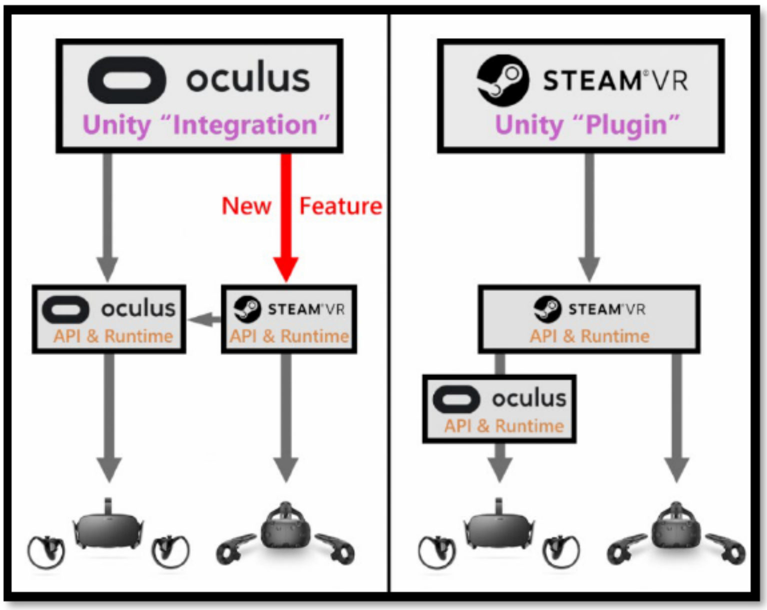

Figure 8. Oculus Supporting HTC Vive Systems (Heaney, 2018)

When developing for either of the above platforms, the content creator will support a VR platform of their choosing, configuring inputs based on the chosen platform. When the application is published it will run on this device by default. However, connecting the opposite headset is now detected by the computer, with buttons automatically being remapped to run on the previously unsupported device. This is a step forward for development as it opens the door for far more users to gain access to content.

Since the launch of the first Oculus developer kit in 2013 (Ingraham, 2013) there has been a growing market of VR headsets, with over sixty different headsets available as of 2019 (Delight XR, 2019). From 2016 to 2019 the number of headsets connected to Steam VR has grown from almost nothing to now surpassing one million devices as shown below (See Figure 9).

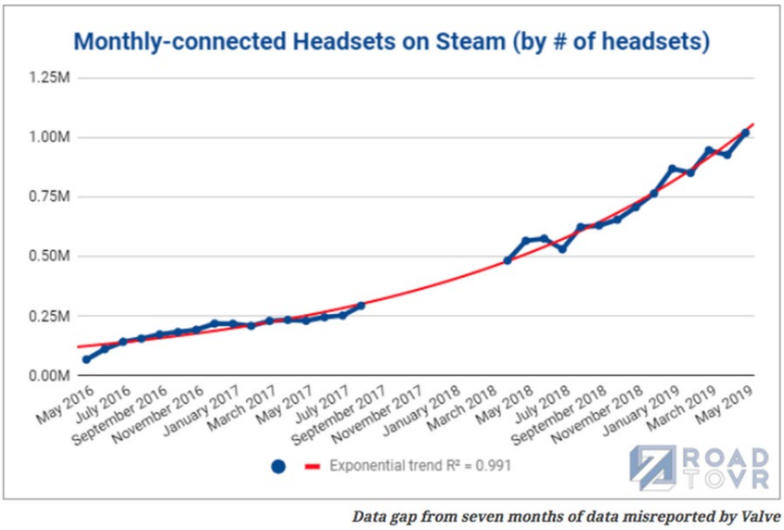

Figure 9. Monthly-Connected Headsets on Steam (Rogers, 2019)

With standalone headsets such as the *Oculus Quest* (Oculus, 2019) and *Vive Focus Plus* (HTC, 2019) now beginning to be available to the widespread public, VR is more accessible. Standalone headsets allow users to experience VR without a PC connected to the device, the headset itself powers the experience. Whilst PC connected numbers are still high, being able to access VR without a high-end PC will allow a general audience to experience what early adopters have been investing in for a number of years. It is estimated that the *Oculus Quest* sold hundreds of thousands of units in its first year alone (Boland, 2020).

With these sales figures, more people than ever before are trying out AR and VR. People are experiencing content in new ways. The virtual worlds can now be stepped into, allowing for a better awareness of space. Instead of viewing digital content on a display, the world is represented in 1:1 scale around a user. This means people can walk around in VR or place objects using AR exactly as they would in real life. By ‘placing’ objects using AR, this involves people looking through a phone screen or via AR enabled glasses to integrate 3D digital representations of objects into what their eyes see before them. Objects are rendered in real-time, meaning the data sets are live and no footage is pre-recorded. Interacting with live data in this way is helping improve the overall product experience.

Headsets and game engines make it easier to get product experiences into the hands of customers, but before this takes place the challenge for product designers is adapting their product development pipelines to include content that can be utilised by game engines. One key example of a challenge that needs to be overcome is how to implement files used in the design world to work in conjunction with games technology, without creating more work for the designer. Game engines cannot visualise CAD data as it is built in a different format to 3D polygon models. CAD software typically generates data in NURBS format, using mathematical calculations to represent 3D (Palamar, 2015). This NURBS data must be converted into a polygon format in order for the computer's graphics processor to display it. Game engines typically require 3D content to be in native polygon format avoiding the intensive computation associated with NURBS data. In short, designers typically use NURBS data due to their high degree of mathematical accuracy and parametric flexibility, but this will not work in a game engine. Any visualisation tool for design has to combat this issue. The 3D file essentially has to be rebuilt in polygon format. This issue has been overcome in the past using combinations of software such as *SolidWorks* (Dassault Systèmes, 1995) and *MeshLab* (ISTI-CNR, 2005), but this process often involves "shuffling" between the two applications before a desired result is achieved (Dixit and Gosh, 2018). This could easily become a painstaking process for developers or end users converting files themselves. Software has since been developed to address this issue including *PiXYZ*, a CAD converter that is compatible with the *Unity* engine (Alba, 2018). The previously mentioned *Unreal Studio* package also allows for developers to easily import and work with AEM (Architecture, Engineering and Manufacturing) files through their *Datasmith* platform (Hong *et al.,* 2020).

Whilst these software solutions are great in speeding up the conversion of complex designs and making them ready for use in a game engine, they still require time and effort. This can add hours to the development process. For product designers to truly be able to use technologies such as AR and VR in their workflows, their data must be instantly available on a device, no external conversion process or tools required. In 2019, automotive manufacturer Daimler released a preview of their new *Engineering Hub* platform in which users can open CAD data at runtime and view it in VR (Daimler Protics, 2019). This provided a glimpse of the future with easily accessible data conversions being presented as a one-click solution. If this becomes more widely available, it will remove time spent on converting data and remove this bottleneck in the pipeline.

Whilst the support of hardware and software is good news for the development community, the research carried out considers how this can benefit design. If we consider a test space in which concepts can be shared, edited and saved for future reference. Making this a 3D test space already allows for further interaction such as picking things up, adjusting positions etc. Also, allowing all of this information to be networked and live synced with a room full of virtual designers, located thousands of miles apart gives a clear signal at why this technology is the future of design. Seymourpowell use this technology daily and the positive impact of this can be viewed in the results chapter (Chapter 5). Although developing such collaborative technologies requires investment and can take time to install, the goal is to reduce time and money long term. Many also see it as a natural evolution of the design world (Duncan, 2010).

2.3.3 VR for Design

Utilising VR for design has shown potential for several years now, with Google's *Tilt Brush* released in 2016 being one of the first commercially successful and sustainable example of VR sketching in the modern era (Google, 2016). This is furthered discussed in Appendix A1.

Prior to this modern period of VR design, there have been several attempts at developing design and prototyping tools utilising Virtual Reality. Disney for example, have been exploring VR from as early as 1992, as a potential ride experience, but also for assisting in the visualisation and design of their theme parks (Mine, 2003). In 1995, Michael Deering developed *HoloSketch*, a 3D geometry creation and manipulation tool. The tool utilised a monitor and head tracked viewing glasses to visualise content that was created with an interactive wand. It was accurate enough at the time for users to "hold up a physical ruler to a virtual object to make (accurate) measurements" (Deering, 1995). Two years later, Chu, Dani and Gadh (1997) proposed what they described as a "multi-sensory user interface for a virtual reality-based computer aided design system". Their goal was to showcase how an immersive design space could assist CAD designers by allowing them to create 3D content using voice commands or gestures, as opposed to being restricted to 2D computer screens. Integrating VR to a CAD designer's workflow has had a lot of potential for the past several decades. In 2003, "VR [was] recognised as the technology at the moment that [could] offer to the user the ability to see and explore in a realistic manner new products or concepts before they exist[ed] in reality" (Hren and Jezernik, 2003). At the same time AR was showcasing potential in similar ways. In 1999, *ARToolkit* (Billinghurst, Kato and Poupyrev, 1999) was released that allowed for the overlaying of 3D geometry onto a live camera feed. By 2004, researchers had created *The Designer's Augmented Reality Toolkit* (DART), allowing for rapid prototyping of designs through placing a vast array of content including images, video and 3D content into an augmented space (Bolter *et al.,* 2004). The evolution of design tools from these early examples have helped shape the applications of today.

Being able to not only view content in a 3D world but also develop and build within this space is an area that is of high interest to many different organisations. As VR hardware has become more common, tools have been created that give designers the ability to create and brainstorm 3D ideas quickly without having to carefully construct these on a traditional PC setup. *Microsoft Maquette* (Microsoft, 2018a), a design and creation application for VR created by Microsoft, gave an insight into how quick and straight forward the VR design process can be. An early demo showcased a designer creating a virtual shopfront with various items in less than a minute, with the highlight being how simple it looked thanks to straight forward controls and easily accessible tools (Virtual Reality Trailers, 2018). Those that have used the software since have described it as having "fluent control" (Leoyakxi, 2019) and have found it "enjoyable to work in" (DishItDash, 2020). Prior to this, *Gravity Sketch*, has established itself as one of the major 3D applications for headsets (Gravity Sketch, 2017). *Gravity Sketch* integrates many toolsets commonly found in CAD and 3D modelling packages allowing designers familiar with these applications to begin working inside VR. Whilst the software has garnered vast success after being valued at £6.5 million and with £1.25 million in investment raised (Digital Catapult, 2018), the approach of giving access to many complex 3D features still comes with a downside. It can make it incredibly difficult for new users to begin designing, particularly if they are unsure of how to even get started. Tools built for designers and new users alike, need to be made with simplicity and ease of use in mind. If tasks feel like a challenge, designers will return to software they are comfortable with and new users may even switch off before attempting to design any products.

As well as sketching and constructing models inside VR, other design tools are also available. Platforms such a *Storyboard VR* allow for brainstorming ideas and linear timelines to be outlined (Artefact, 2016). *Storyboard VR* mimics the early design phases of repeatedly sketching out ideas and explaining concepts with sticky notes. This virtual mood board allows 360° imagery to be combined with 3D text mark-up, providing a creative way to capture brainstorming sessions. Designers can step into each other's virtual minds as they become more immersed in an idea, free from distractions in a dedicated project world.

One of the features of VR that has the potential to assist the design industry the most is the collaborative opportunities it brings. People can be anywhere in the world and work on a design together, whilst standing in a shared 3D space. Software such as *NVIDIA Holodeck* (NVIDIA Corporation, 2018) and *The Wild* (Wild Technology, 2019) have shown that multiple users wearing headsets can easily work together on a design across multiple locations via an internet connection. It is through innovations like this that VR can help break down barriers such as international travel, making it cheaper and faster for people to work around the globe together. Despite this, *NVIDIA Holodeck*, *The Wild* and many more like these all have similar functionality but have not seen mass scale adoption. The software and hardware need to improve and provide a true step up for product designers, the methods of achieving this being something this research project looks to explore.

Designing in VR, opens new possibilities for designers and the design process. Whilst there are existing solutions allowing for design using this medium, the goal of this project is to develop software with the role of product designers further in focus. This “by designers, for designers” approach aims for any tools created to be best positioned for use within industry as they will have been tested and developed on live projects, to better evaluate their effectiveness.

2.3.4 VR for New Toolkits

As well as inspecting and editing models, VR can be utilised as a new technology for carrying out a wide range of tasks. Engines such as *Unity* and *Unreal* make it easy to develop and create interactive software. These engines provide frameworks for creating tools to fit user needs, with the ability to develop a wide range of functionality for any project. Both platforms can be used to create online and offline content, with features such as saving and loading being easier than before to build into any application. This is thanks to sample content available online from other users of each engine. In the past such functionality would have to be programmed entirely from scratch. Other tools, such as those that facilitate the changing of colours, scales, materials or even entire pieces of geometry can all be used in different ways for specific use cases.

These options can be incredibly useful, but so is simply being in a shared VR space. Applications such as *MeetinVR* (2019) have emerged in recent years allowing people to simply have a conversation in the same virtual meeting room. This can be more powerful and interactive than a standard video call as people can use their body language to express themselves more clearly. Expanding on the use cases of the standard video call can be done in several ways. Other methods such as those seen in *Vuforia Chalk* (PTC, 2017) and *Dynamics 365 Remote Assist* (Microsoft, 2018b) have involved being able to overlay information in an augmented display. Users can call specialists for support who can then annotate on screen for them to see in real-time. This can make it easier for novice users to get support in tasks and obtain expert opinions from anywhere in the world in a more direct manner. Simple annotations and voice communication are just a start. To truly innovate in this space new forms of communication and interactions between users are yet to be discovered. It should be simple and easy for the remote user to access and present any additional material they need to help whether it is design documentation, web searches or tutorial content. Until software can fully replace someone standing next to a user and assisting them, there is room to improve.

Another example of new tools has been to utilise the power of placing a camera anywhere in a virtual environment to direct and film shots. With the ability to quickly move anywhere in an immersive world, we can see 3D elements from any angle. Jon Favreau (BBC News, 2019) stated that when filming the latest *Lion King* film, they built the entire computer-generated world first and then moved around inside a VR headset to determine the best shots for the movie. This process has been explored in more detail as part of this research project. Placing cameras in a virtual environment allows for quick evaluation before the lengthy setup and production requirements of filming on location. An added benefit is that filmmakers can also experiment with equipment they do not currently own, minimising expenditure on unnecessary products. With the cost of high-end film production cameras ranging into the hundreds of thousands of pounds, the ability to fail early and cheaply can benefit expensive productions. Whilst this may not be an issue for a major studio, large numbers of independent directors can appreciate a tool where they decide on their setup before hiring or purchasing new devices.

VR can explore these new methods for carrying out tasks. This project seeks to further explore ways in which VR can help design, as well as other industries, discover new ways to evolve their processes.

2.3.5 Games Technology in Wider Society

The wider world uses games technology in day to day life, such as interacting with applications on their phone or through technology at their workplace. Product designers have to consider this as part of their process for creating new products. Technology is part of our day to day and many of the pieces of technology we take advantage of were once used purely for entertainment purposes. One of the primary examples of this is training tools or simulators.

Racing simulators have been a form of video game for decades, the first of many being *Gran Trak 10* (Atari, 1974). Since then racing games have gone on to become realistic representations of the sport itself. Similarly, flight simulators have established themselves as an entertainment product. However, with some professional and even amateur flight simulator rigs reaching into thousands in terms of costs (Flight Simulators Limited, 2020), many people have seen the training potential of these. Now that simulator training exists, many transport authorities require employee time spent in a simulator to become better equipped to take on their role. Transport for London recently utilised a simulator to train drivers when their new signalling system was introduced (RailStaff, 2018). For pilots, as well as standard medical checks, they must also practice on a simulator every six months to practice emergency procedures under assessment (FlightDeckFriend, 2016). The transport industry can be assisted in many ways through design, training and operations, with game design and technology playing a pivotal role.

In the medical industry, game engines and their output have been used in specific situations to provide better patient care and planning solutions for hospital staff. Management games such as *Cities: Skylines* (Colossal Order, 2015) and more closely related, *Two Point Hospital* (Two Point Studios, 2018) have been popular for years with their mechanics of managing resources proving to be an engaging challenge for entertaining a broad range of players. They reflect or mimic the real world where management of a ward or set of patients can be challenging for hospital staff. Researchers in the Netherlands created a virtual emergency ward for staff to practice tending to patients (Dankbaar *et al.,* 2014). They found that those using the game performed better on clinical skills, providing one example of the benefits of serious games. A further medical example of serious games was carried out in Germany, where the University Hospital in Cologne discovered that a game simulating emergency room procedure was able to increase medical students' knowledge of the field (Berlth *et al.,* 2019). Another issue facing the medical community is mental health and the issues it can lead to. Research has shown that games can be designed to predict people's responses based on their reactions to on screen content (Bagga, Chandra and Kahol, 2013). This provides a powerful tool that could be expanded on in terms of use cases. Being able to determine reactions from users suffering mental health issues can help prioritise the care they need.

Gesture input was popularised by the likes of the *Nintendo Wii* (Nintendo, 2006) and *Microsoft Kinect* (Microsoft, 2010). These devices allowed people to move their bodies in a natural way to control visual elements on screen e.g. swinging a controller to act as a tennis racket. The *Kinect* provided a way for people to interact with content with their bodies acting as the controller. As a novel input device this opened a range of possibilities, allowing workplaces to trial new methods of interaction. The latest *Kinect* model, the *Azure Kinect* integrates cloud technology along with this full body sensor and subsequently has made further innovation opportunities possible (Microsoft, 2019b). Enterprise customers are already making use of this device. Medical service provider Ocuvera are using it for patient monitoring, with the camera detecting if someone is about to fall and alerting a member of staff (Warren, 2019). Retail technology provider Ava Retail uses the sensor to detect items that a customer has picked up and automatically bill them when they walk out of a store (Novet, 2019). The device itself can capture information by listening and watching a specific event. This information can then be put to further use by storing it in the cloud, allowing developers the ability to access this data and "quickly build, test, and develop… predictive models using state-of-the art machine learning algorithms" (Barga, Fontama and Tok, 2014, p. 21). What started as a new form of gaming, is a device that could revolutionise the world. The *Kinect* can be described as having evolved from a handsfree gesture device, to a powerful computer imaging piece of hardware. Gesture control has its merits, but if an interaction is failed to be detected it can become frustrating or potentially problematic. With the hardware improving, examples such as medical and retail solutions are more likely to be relied upon. Again, this depends on people's trust in the technology based on what it can show it is capable of.

Overall, whilst technology can undoubtedly enhance pre-existing workflows, it is new workflows and methods enabled through future technologies that have the potential to change entire industries.

"You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete"
– Buckminster Fuller (Sieden, 2012, p. 358*).*

Games technology has changed product design before and with the growth of new software platforms alongside revolutionary hardware, there are many potential opportunities for it to further innovate the field of product design.

3 Case Study Analysis

Several case studies were carried out to explore examples of games technology that are available and that benefit the product design industry among others. These case studies analysed AR, VR and other forms of technology that have all brought benefits in a number of ways. They also helped to inform the design of the applications developed throughout this project, based on the information gathered during research. The topics explored include:

1. VR for Concept Design – exploring drawing and design tools for VR.
2. VR for Production – identifying VR storyboarding and planning techniques.
3. AR for Product Development – investigating the benefits of AR for design.
4. Learning Through Games Technology – research into games used for education.

Each case study analysed the overall innovation being explored by identifying common examples already being utilised. The impacts these innovations had on design were then explored before the areas that such technology would disrupt were considered. Finally, a closer look into not only current use cases, but potential use cases for the future were researched for each innovation. The full case studies can be accessed within Appendix A.

3.1 Innovation Overview

Each of the innovations explored were identified as products or solutions that the product design industry could utilise to better their current practices. Whilst the solutions developed through this research looked to develop new approaches to product design, it was observed that there are many existing solutions that can already further design in general. Applications such as *The Wild* (Wild Technology, 2019) and *MeetinVR* (2019) currently provide the ability to collaborate from anywhere in the world. People can join the same virtual space and design or discuss together. Solutions such as these and others analysed in the full case studies range from being able to provide a new form of discussion, to providing entire platforms for designing products of the future.

Figure 10. MeetinVR (MeetinVR, 2019)

As well as discovering technologies for collaboration, many of the VR solutions on offer had reinvented the wheel, providing new tools and processes to improve on past practices. These included new methods for storyboarding, planning or even presenting to clients. While some of the applications had specific use cases tied to a particular company, many of the principles could be expanded upon for a wider audience. For example, many of the new filmmaking technologies implemented for various Disney projects using the *Unreal Engine* (Unreal Engine, 2019) could be repurposed for other studios going forward.

As well as advances in VR, AR has had many exciting opportunities for the world of design. Several brands have developed virtual room planners, allowing their products to be displayed in a customer's home virtually before purchase. This provides the enormous benefit of customers being able to try before they buy, especially when it comes to large purchases such as furniture. Unfortunately, this concept is still to take off with more brands, although with the increasingly available access to AR on modern smartphones it seems inevitable that brands will begin to further embrace such technology. AR applications such as these provide the ability to view model data anywhere via a mobile device. Designers can utilise this for product presentations and sharing concepts with clients at the touch of a button.

Figure 11. John Lewis Virtual Sofa (Hatton, 2020)

All the innovations explored show potential and promise for the future product design world. One final avenue explored was how innovations in games technology can help people learn and understand. Being able to train and simulate in new and better ways can unlock new possibilities. Performance tracking, process monitoring, virtual examinations and more are all enhanced by games technology. It was discovered that many of these solutions not only benefit users but capture data that product designers can use to obtain an insight into how people are being educated on a product or process. Tools developed by companies such as *Strivr* can track where people's vision focuses when looking at a store shelf (Strivr, 2020). The technology uses a VR headset with built in eye tracking to access this data, providing brands with insights into whether their product stands out to the average consumer.

Figure 12. Strivr Showing a User's Focus via Orange Dots (Strivr, 2019b)

3.2 Impacts on Design

There were various impacts on design outlined in each case study, with a variety of applications and approaches presented that could change processes and revolutionise workflows. *Gravity Sketch* (2017) and other virtual design platforms were some of the most common examples, with VR tools providing new ways for creating content in a 3D space. These examples began with the basic concept of sketching and expanded up to collaborative environments where common 3D toolsets were accessible. Much alike the development of *Reality Works*. Collaboration was a key feature of many observations. Being able to review designs or create them entirely from any location on multiple device types was critical in saving money and time for organisations.

Virtual production provided the benefit of being able to visualise tasks in a more immersive manner. Applications such as *Storyboard VR* (Artefact, 2016) made it possible to plan out entire narratives or design stories from within a headset. By doing so people were able to 'step into' a concept and become immersed in its messaging. The main drawback of course with all these scenarios being that people had to put on a VR headset.

Figure 13. Establishing Worlds in Storyboard VR (Artefact, 2016)

Combating any reluctance to wear a headset were augmented reality approaches. AR model viewers and mobile applications for presenting again saved time and money, whilst providing an easy approach to analysing content. Applications such as *Vusar* (Vusar, 2019b) make it easy to send designs over the cloud for feedback. For example, a designer can review their design using the application and then upload the design to send it to others in the same time it would take to send an email. In the past physical models would have to be sent around the world.

Figure 14. Reviewing Designs in Vusar (Vusar, 2019a)

Not only can content be sent digitally anywhere, the analytics and performance of designs can be evaluated using games technology. By building in performance indicators and recording tools, AR and VR can track how people are using a product. For example, sports training applications can record a user's workout or training routine, and this can inform what types of product solutions give competitors the upper edge. *Strivr* use their platform as part of American Football training, helping multiple teams increase their abilities by putting players in virtual representations of game time scenarios (Strivr, 2019a).

3.3 Areas Disrupted

By analysing the areas disrupted by technology, we can begin to understand how the product design pipeline is likely to change in the future. The design process is changing, it was shown that with the new powerful VR solutions out there that some people are skipping sketching altogether and simply starting to draw in VR. The aim of this is to allow for designs to get to a review stage more quickly for feedback and changes. With the ability to review content digitally it was also believed that an increase in design iterations would be possible going forward. The design process is changing to meet the demand of technology and workplaces will have to adapt also. Organisations may have to consider how office space will be catered to VR spaces.

Educating others about designs is also easier via digital experiences. The more people experience something the more they become familiar with it. Instead of learning basic facts and specifications from a sheet of information, people can be shown the real-world benefits of a design via a digital platform. This was analysed by looking at simulations and training practices in other fields. An example that stood out during investigation was one where submariners found it easier to learn safety procedures via a game rather than memorising locations of equipment from reading a piece of paper (Cressey, 2011). Applying this to design, the more designers can physically interact with a product, the more helpful it is for understanding how that product will work and where its key features sit.

3.4 Current and Future Uses

After researching the various topics, it became clear that there were several solutions presently available that could assist the product design world as well as several developments on the horizon that could provide game changing solutions to the world of design. As discussed, there are currently many drawing/sketching applications available for VR, the most consumer friendly being *Tilt Brush* by Google (Google, 2016). This gives artists and designers alike the power to create and grow their ideas. The ability for mass adoption of virtual drawing already exists and going forward devices such as the *Oculus Quest* (Oculus, 2019) can increase user access. The *Oculus Quest* is one of several consumer facing wireless VR headsets released in the past few years. Due to their consumer facing approach it has led to cheaper hardware that is acceptable for the masses. This also makes it easier to get VR hardware in the hands of designers. What was once a high investment for organisations, VR is now available to almost anybody. This means that experienced and new designers can both begin to integrate VR into their workflows.

Shifting more to enterprise however, virtual production and planning is presently available with revolutionary filmmaking techniques. Virtual camera setups using *Unreal* and digital environments that can be customised in real-time are beginning to push the boundaries of what is possible (Unreal Engine, 2019). Soon it could be possible to phase out a large percentage of post-production on a film project, with all digital assets, lighting and colour correction available as part of filming. This again would save time and money and allow for experimenting with different digital setups whilst all cast and crew are present on set, potentially improving the look and feel of the final product. Using this new hardware, however, is still far out of reach for lower budget productions, with expensive technology including large LED panels being required to simulate lighting and backdrop environments.

A more affordable development has been mobile AR and the ability to view digital content through a common smartphone device. Whilst people can already look at 3D content through their phone screen, it is expected that in the near future AR glasses will become available which will allow digital content to become a greater part of everyday life. People will be able to experience digital content from promotions and brands just by wearing a set of glasses and walking down the street, although this does open the possibility for a discussion on the ethics of advertising in people’s personal space. Further research would be required into such a topic, but it was beyond the scope of this project.

Lastly, whilst the research into learning through games technology appeared to differ slightly from the focus into product design, the learnings were designed to influence product design research. By investigating how people can learn and be trained through games technology, similar practices can be built into future tools for product design software. One of the most useful training applications came from *Strivr* who developed software that utilised eye tracking to monitor people’s behaviours and interests based on what they looked at (Strivr, 2020). It is implementations such as this that could greatly benefit product design when trying to develop concepts for mass market appeal.

4 Research Methodology

In order to assess the ways in which games technology can influence and therefore evolve the product design process, a mixed methodological approach was undertaken, and the results analysed. This approach outlined by Creswell (2007) aimed to analyse observations and experiences of games technology gained through qualitative research. This qualitative research was carried out via experimental research and development of prototypes. This was then used to evolve existing software and create new product solutions, which later informed a quantitative study into the main applications developed as part of this research project.

Each method assisted in gaining various levels of insight into how technology can cause an impact at different stages of development. The three main stages of evaluation for how games technology can impact product design were:

- Experimental Research and Development
- Reality Works
- VR Camera Tool

Through research and experimental prototyping, a portfolio was built up of potential solutions that did not merit further testing or development. This portfolio work was undertaken to inform the development of *Reality Works* and the *VR Camera Tool*, as well as to gain a greater understanding of the hardware and software. These prototypes also explored games technology outside of those used in the applications above, and the methods in which they too could benefit the design process. By capturing qualitative data and uncovering the positive and negative aspects of the many technical solutions explored, a greater understanding was gained of how best to introduce such technology into a product design world.

Before undertaking the development and testing of *Reality Works* and the *VR Camera Tool*, development was also supported through a series of case studies (as described in Chapter 3). These were carried out to better understand the products and solutions currently available in the field and explore what has worked so far, as well as what has not. The case studies provided insight into the applications being developed or researched some of the influence games technology has had on the field of design. Each case study was structured to analyse the positives and negatives of the technology being explored, to feedback to the development process the features and functionality most helpful for users.

Reality Works and the *VR Camera Tool* went through thorough testing and evaluation including quantitative analysis as outlined in the findings below (Chapter 5). The results of this analysis aimed to provide a collection of insights on how best to utilise games technology in a product design sense. The applications were tested on their ease of use and robustness when given to new users. The data analysis highlights the various aspects through which both *Reality Works* and the *VR Camera Tool* were tested and indicate whether or not these systems could refine product design pipelines in the future.

4.1 Integrating Games Technology into Product Design

Working as an integral member of the Creative Technology Team at Seymourpowell allowed for a direct opportunity to experiment and build upon the use of future technologies as part of the process of the wider product design department. As part of this team, one of the common goals was to constantly evaluate new and exciting software solutions. The typical approach chosen to do this was to build tools in house, allowing for immediate feedback on what works and what does not as part of the product design process.

4.1.1 Finding the Right Method

As the product design team at Seymourpowell consists of personnel with a wide range of backgrounds and experiences, the tools developed to assist the product design process were built and refined with the purpose of benefiting all those involved in their use. However, toolsets were often built for more than just designers. No matter the background of an individual, they must be able to access and explore digital content in a similar manner to that of the designer. That may mean loading an app, pulling on a headset or stepping into a multiplayer experience. Whilst it may seem challenging to get anyone to access new technologies with ease, it has also been the overarching principle of the Creative Technology Team, which informed one of the development goals of this project. This was to ensure any game technology provided accessible design to all. Controls were built to have simplistic input. The user experience was based around having to consume as little content as possible to understand the bigger picture and if it any point this was not achieved, the software was reworked, redeveloped and refined to ensure that any new tool was not just a cool piece of technology. New tools were built to evolve a process, not add a new step in the pipeline.

Following this design-for-all approach, the user experience design of the applications developed focused on providing value to as many different user groups as possible, increasing the potential number of people interested in the technology. One of Nokia's most influential designer's Christian Kraft spoke of why this is important. "To make your new technology a success, you have to provide value to the users from day one" (Kraft, 2012, p. 65). Kraft goes on to outline the steps he takes when creating a user experience for a technical innovation (Kraft, 2012, p. 67):

1. Identify target user needs.
2. Identify potential capabilities of the new technology.
3. Put the technology in the centre.
4. Innovate solutions based on customer needs and technology capabilities.
5. Document the results and process the output.

The software solutions generated from this project aim to follow this approach. Whether it is virtual reality, interaction mechanics or any other technical development, the needs of the user are critical. By defining the desires of the target audience, it shapes the technology to make it fit for purpose in a world where technology is constantly evolving. By focusing on the needs of those using the software and working within platform constraints, key functionality can be built to best suit the end user.

In the case of this project, product designers were able to clearly evaluate designs with *Reality Works*. Whilst they could also direct and position cameras using a *VR Camera Tool* without the need to learn any new skills.

Whilst product designers were likely to be familiar with the toolsets of each software, the onboarding process for introducing a user from any background to *Reality Works* and the *VR Camera Tool* was built with easy to understand functionality in mind. The design of the test sessions and subsequent order of tutorials introduced was planned to get people up to speed with simple controls as quickly as possible, before moving onto complex tasks (see Chapter 4.5.2). James Paul Gee (2005) refers to it as the “Fish Tank” approach in which game players are placed in an environment where they learn the basics first to avoid becoming overwhelmed with all the available functionality. Games have popularised this approach of “gradually releasing the restrictions [placed] on the player”, with common examples including in time “giving access to more islands in Grand Theft Auto, or making you more badass in World of Warcraft as you level up” (White, 2014, p. 47). This teaches users how to play from within the experience itself. Whilst no functionality was restricted in *Reality Works* or the *VR Camera Tool*, the tasks given to the users began with the most basic of controls. This allowed users to build upon what they could do, starting with the easiest mechanics to learn. Gee has also discussed how humans “learn from experience” and that “media designers, and artists design experiences for [people]” (Gee, 2016), allowing them to gain further insight about a topic through increased interaction. Whilst users could pick up any game or software and likely obtain some knowledge of its functionality on their own, by having the experience designed for them it can make it easier to understand. The software created for this project follows this approach, with each application putting the basics first, then once users are comfortable, they should naturally progress to further toolsets.

4.1.2 Design Approach for Development

The approach taken for the development of prototypes and software solutions generated by the project was the Double Diamond Approach (Design Council, 2007). This allowed for goals to be outlined at the start but also to be redefined throughout development based on feedback from stakeholders as well as general feedback from testing of the technology.

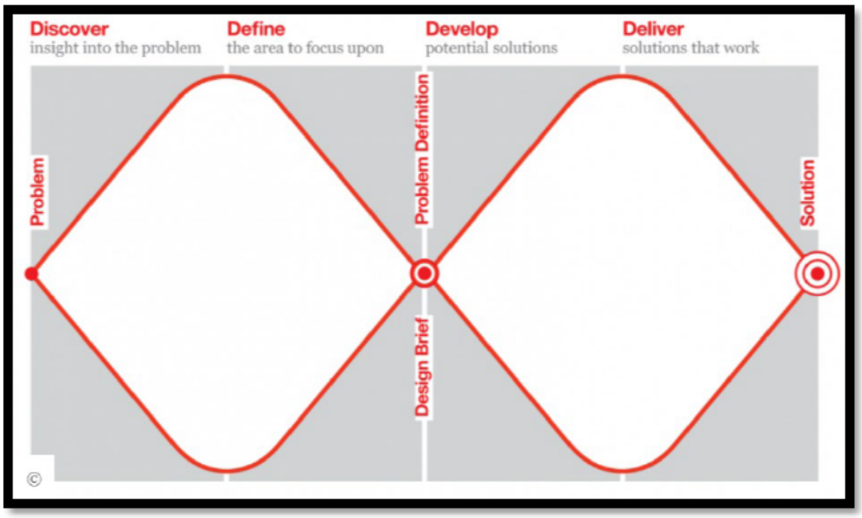

Figure 15. Design Council (2015) – Double Diamond Approach

Each piece of software developed was broken into a variety of features that were outlined in terms of importance and the objectives they would focus on solving. Each feature was split into subsections using a top-down strategy as part of the design methodology. This was to ensure before implementation that benefits and challenges were clearly defined to provide an insight into what was being developed, the impact of this, as well as all the aspects required to deliver a successful end-product.

The Double Diamond method also integrated an iterative development process. As discoveries were made through the user testing process for *Reality Works* and the *VR Camera Tool*, aspects of the software were redefined and built with new insights. These new insights helped increase the ways in which this research could positively impact product design.

Throughout the development and during the testing period, VR design guidelines were adhered to. These best practices describe the optimal methods for creating tools utilised via a wearable headset and are intended to make tools as easy to use as possible, a key goal of this project. These are (Bowman *et al.*, 2017, p. 447):

1. Move wires and cables out of the way or use wireless.

2. Provide physical and virtual environment barriers.
3. Limit interaction in free space. Provide rests in user movement.
4. Design for short sessions and encourage breaks.
5. Consider the use of props and passive feedback.
6. Consider real-world tool and practices.
7. Consider designing 3D techniques using principles from 2D interaction.
8. Consider alternatives to photorealistic aesthetics.

These guidelines had to be carefully considered in order to create a solution that correctly used the technology, was safe for end users and was appropriate for product design usage.

Areas of the product design pipeline including research, product analysis and the design of a physical product were also embedded as part of the quantitative capture of data. Test processes and the resultant data were then carefully considered in accordance with the Double Diamond approach to ensure that no matter the outcome of the test, the resultant data would inform the project goals. With the overall consideration of the project being to evolve product design, the various testing and development work sought to discover the best possible understanding of how the three main methods of evaluation (experimental research, *Reality Works* and the *VR Camera Tool*) could achieve this.

4.2 Experimental Research and Development

Initial work built up a portfolio of prototypes. These were constructed to ensure that research covered the extensive number of technologies that could be applied to product design. Further prototypes were frequently added over the course of the project timeline. Whilst this research does not cover an exhaustive list of all solutions available today, the prototypes explored, provided insight into the many ways in which games technology can enhance the product design world. These directly informed the development of the two core tools, *Reality Works* and the *VR Camera Tool.*

Each application developed put design thinking at the forefront. Whilst fun and engaging mechanics can make it easier to work with software due to the added enjoyment factor (as noted in Appendix B1), no development was completed purely based on the fact that it was fun. Factors such as time saving or making tasks easier for designers to carry out were the main criteria focused upon. *Reality Works*, the *VR Camera Tool* and the many prototypes discussed below all aimed to create new ways for games technology to serve the masses, just like the Bauhaus did in its portfolio of design solutions.

Each experience was developed in accordance with game design ‘rules’ (Salen and Zimmerman*,* 2004, p. 125). Such rules ensured each prototype was consistent in its approach. These were applied to “limit player interaction”, to be “explicit and unambiguous”, to be “shared by all players” and they were “fixed” as well as “binding”. Salen and Zimmerman describe these as the “common traits” of games, allowing for a structured experience to take place. By placing rules on a game, we are creating a framework for the experience, providing helpful constraints to ensure the closed system works as desired. Otherwise, if no rules were applied to an experience, users may become lost or overwhelmed. Whilst usually applied to more traditional games, maintaining the approach of the rules above ensured any product design prototype developed had a set of boundaries to create a meaningful experience.

One of the main research avenues explored was the use of AR to view products and convey information. Utilising the latest augmented reality software development kits allowed for applications that would bring digital content into the real world on a mobile device. Various prototypes made use of this including navigation experiences, where users could be given more location-based information about a product by bringing up a local map to explore. A more general approach was to put 3D content into AR allowing for the viewing of products anywhere thanks to the portability of modern devices. Being able to easily share and send AR content is giving designers today the ability to easily evaluate their designs in real world locations by simply opening a model in AR and viewing it in situ.

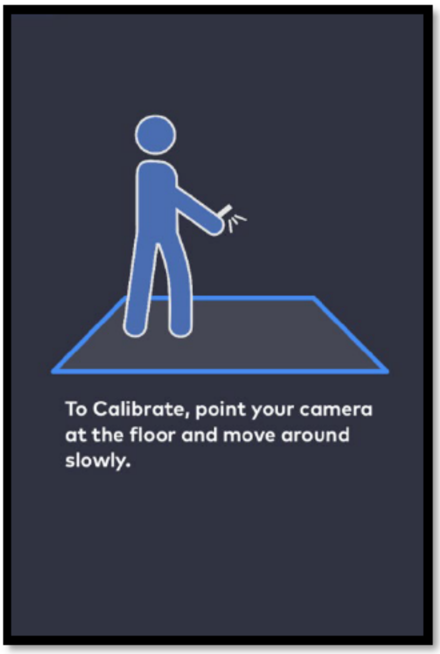

Figure 16. Example of Simple Room Scanning Instructions (Kurbatov, 2019)

AR first requires the user to scan their environment and this can become challenging for novice users. With clear instructions and smartphone hardware from 2018 onwards, most AR tracking applications perform to an acceptable standard for reviewing content. More information on AR product development can be found in Appendix A3.

Another key area of research was body sensors and trackers used to capture gestures as a form of input. Sensors such as the *Leap Motion* (Ultraleap, 2013) can track input from hand gestures, or in the case of a device like the *Kinect* (Microsoft, 2010) even full body skeletal tracking. This provides a useful method of interaction as people can use their bodies as a controller without the need for an additional device.

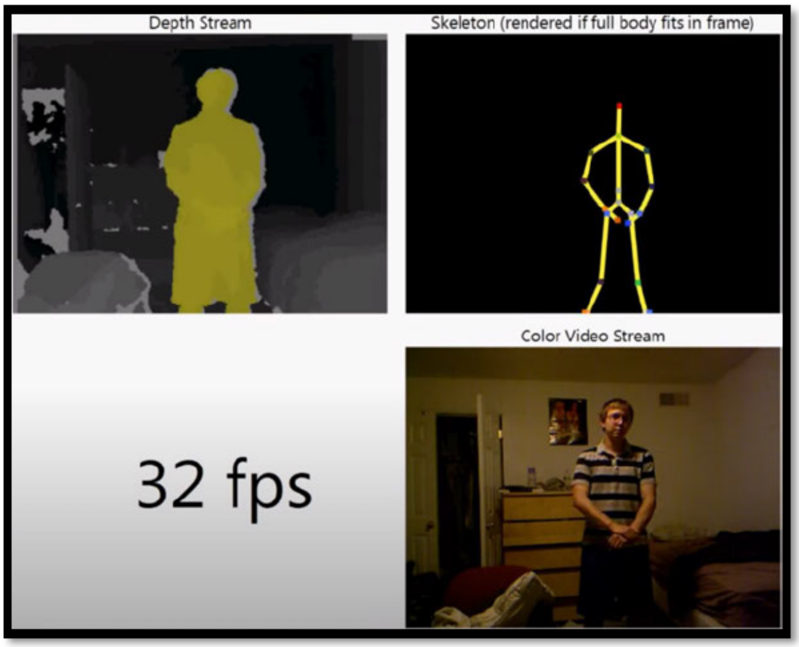

Figure 17. Kinect Skeletal Tracking (Coolrudski, 2011)

Gestural interaction provided new, exciting control methods, but ultimately lacked powerful use cases for the design process. Aside from the ability to generate input without physical touch, standard tasks such as sketching or taking notes were difficult with such devices. This was due to the fact that there was no physical feedback if sketching with gestures in the air, ultimately users would have to become accustomed to no resistance to better use this form of input. One main disadvantage with the *Kinect* and *Leap Motion* was the overall quality of tracking. Whilst impressive in nature, it was possible for the sensors to not detect gestures or lose tracking of body parts enough times for these to be fully 100% reliable systems. Various tests of standing in front of the *Kinect* or waving hands over the *Leap Motion* determined that they could be problematic in critical scenarios where failure was not an option.

Figure 18. Leap Motion Tracking (Miller, 2019)

Whilst these additional pieces of hardware were useful and had many applications, they are ultimately limited in their use cases. To be able to prototype in an unrestricted manner, Arduino based solutions were explored.

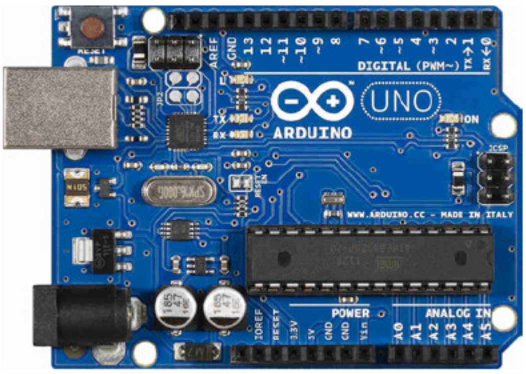

Figure 19. Arduino Board for Communicating with PC (Austin, 2016)

Arduino is a programming language designed to integrate with electronic components such as sensors, motors, speakers and many more common input and output devices. This provided a way of creating bespoke experiences. Whilst a design tool was not developed using this platform, the research into how Arduino could make any hardware idea feasible was a valuable insight and helped remove limitations on considering new methods for product designers. There were still some drawbacks in that there was a certain level of technical knowledge required to create more complex Arduino circuits and the added challenge for developers of not just writing code but also building the hardware. However, with endless possibilities of components and hardware combinations, Arduino provides the freedom to build almost anything if time and cost is not an issue.

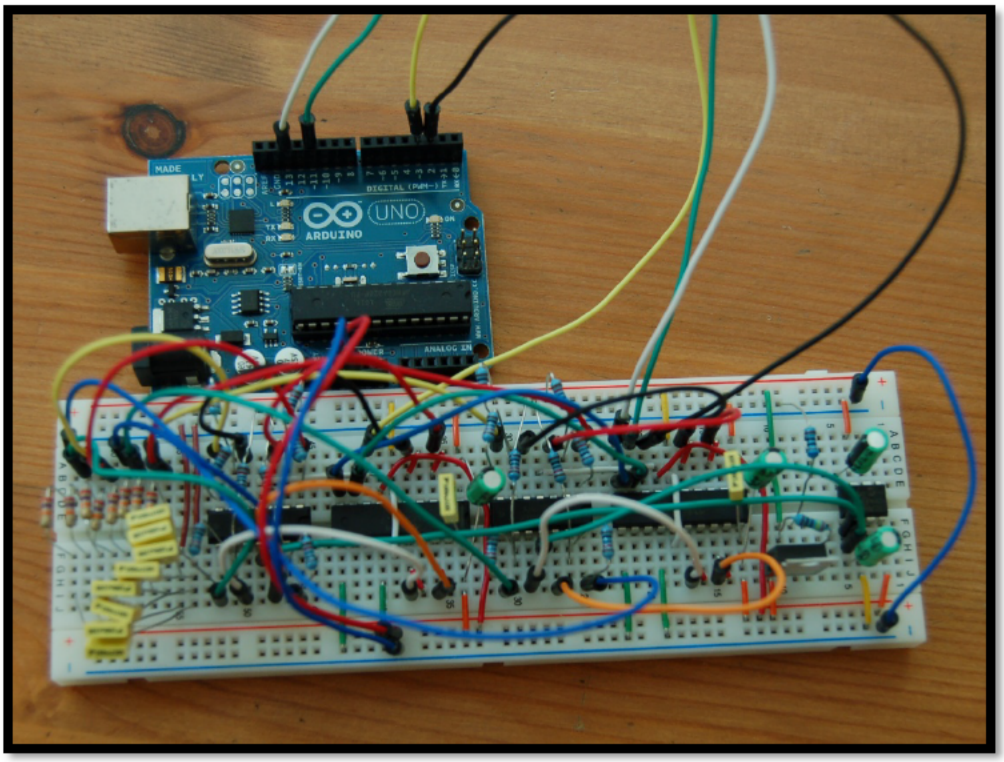

Figure 20. Example of a Complex Arduino Project (Miller, 2019)

Being able to make any experience possible allows for nothing to be off limits when it comes to design. A simpler approach to do this was in the use of *Vive Trackers*. These were developed in order to bring any prop or device into a VR space. This was done by fixing a tracker to a real-world object and then modelling this 1:1 in the VR application. This quickly allowed for objects to be brought into VR including bottles, footballs and even bicycles. Being able to add additional props is key for learning experiences. Companies such as Strivr (Strivr, 2019a) have taken similar approaches to enhance VR learning through developing VR training. Using games technology to assist learning is a large industry, as discussed in Appendix A4. The trackers required additional wiring for VR and were cumbersome in nature, almost 100mm in diameter (HTC, 2018). Whilst this could be problematic with smaller objects, they made the process of enhancing VR experiences with additional objects an easily repeatable process.

Figure 21. Numerous Vive Trackers (Ipas HQ, 2017)

Through each of the experimental processes listed above, qualitative research was captured via developing prototypes that were built to get the chosen piece of games technology up and running as quickly as possible for evaluation. Once ready to be evaluated, various designers at Seymourpowell as well as any other public bystanders would feedback their opinion of each device and their use of the technology was always observed to critically determine the effectiveness of the solution.

Despite there being a wide number of prototypes developed over the course of this research, these helped better understand games technology as a whole and its implications for the future. The knowledge gained here also fed into the development and data capture of *Reality Works* and the *VR Camera Tool* which were more closely explored as a method of futuristic product design.

4.3 Reality Works

A main area of development for this project was enhancing Seymourpowell's collaborative design tool (*Reality Works*). This VR design tool was developed using the *Unity* game engine and built for the HTC Vive headset. The application allows designers to load models into 3D space or create these from scratch. Users can then collaborate internationally with connected peers as they sketch, refine and measure components of a product. A product design can be created entirely from the use of the application if desired. The tool is designed to work alongside current software packages, with the ability to import and export all data into existing toolsets on a desktop PC.

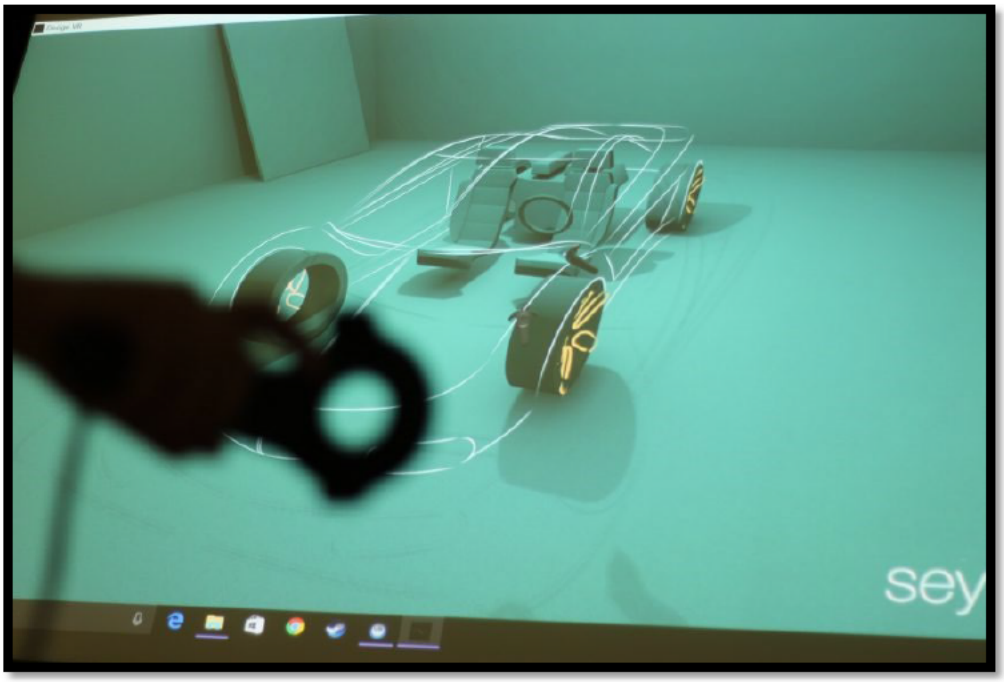

Figure 22. Vehicle Design in Seymourpowell's Reality Works (Aouf, 2017)

Utilising VR as a method for concept design is not a new idea (as explored in Appendix A1) but *Reality Works* was developed as a means of making it accessible for everyone, regardless of their background. Tools such as *Gravity Sketch* (Gravity Sketch, 2017) and *Microsoft Maquette* (Microsoft, 2018a) are perfectly suitable for building ideas, but they require prior knowledge of 3D concepts and tools in order to effectively use these. *Reality Works* started with the simple idea that everyone already knows how to draw, so how does that translate to drawing in VR for the first time?

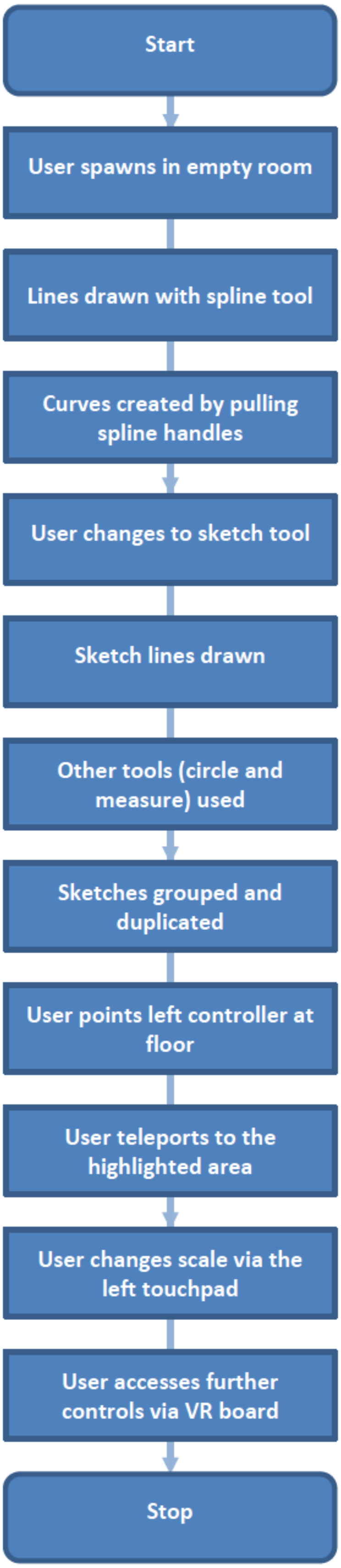

Figure 23. Reality Works User Journey

A shown in the flowchart above (Figure 23) a typical end user journey in *Reality Works* starts from a blank canvas through to a complete product design that can be exported into other software or collaborated with others in the same space. When users first open the software, they are immediately presented an empty room with the spline tool activated. This allows them to draw straight lines with a simple trigger pull but can also allow for the quick generation of curves by pulling the handles on each spline. The next tool introduced is the sketch tool, allowing for simple mark up and free form ideas to be populated in the 3D environment. There are two more tools on the drawing controller that can be utilised, these are the circle tool to allow for perfect circles to be drawn and the measure tool for accurately sizing up objects inside VR. Once these four basic tools have been grasped, more advanced users will begin to pick up how to quickly group and duplicate sketches through a combination of gripping the sides of a controller and pulling the trigger at various points. Sketch lines can also be alternated in thickness and opacity via sliding a finger over the touchpad. Aside from drawing via the right controller, the left controller manipulates the user’s movement. People can teleport by pointing the controller at the floor and pulling the trigger or can change their scale via the touchpad. This functionality makes it easier to work on any part of a design, as physical constraints would typically prevent this. By allowing people to scale themselves down to work on the intricacies of a wheel or to scale up and design on unreachable surfaces, people are given more freedom than when building real world models.

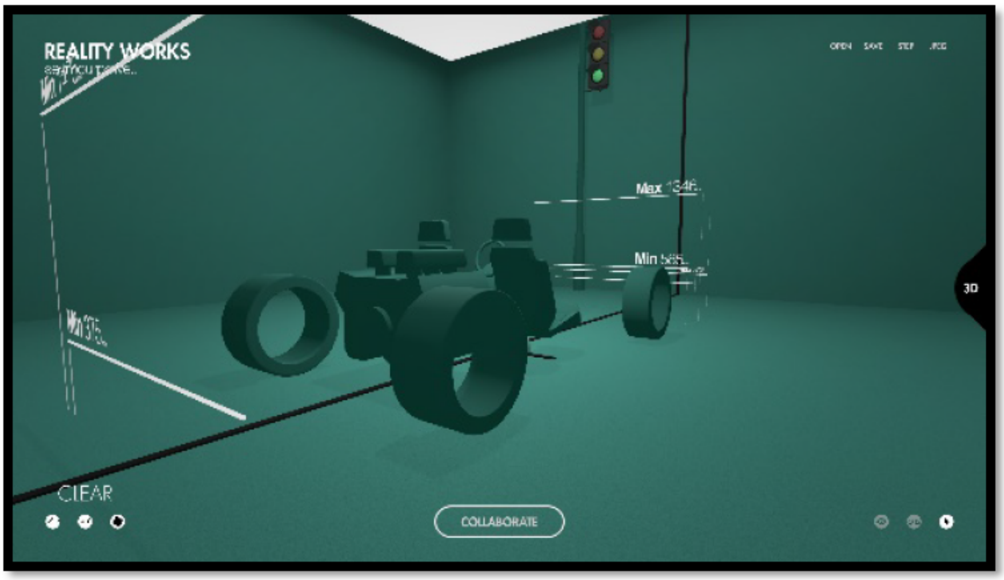

Figure 24. Overlays and Guidelines Inside Reality Works

In addition to input via VR controllers, there are various other buttons that can be interacted with inside the digital environment or on screen through menus on the PC. *Reality Works* contains a series of layers with pre-populated geometry such as car chassis’ and layers containing overlays of design guidelines. The application can also import .obj files, allowing designers to bring in their own work to view in VR. Designers can sketch and refine parts of a design before re-exporting the new data as a .stp file that can be loaded back into a CAD package later. *Reality Works* helps bridge the gap between initial concept to final design through its ability to work from a base model and then export useful CAD data sets. In addition, the software contains save and load support to save all designs and load them back in instantaneously.

All the tools discussed can be used in a multiplayer environment. Whilst all controls are not yet networked (something currently under development), multiple users can join into the same space from anywhere in the world and work on a design together. Users can talk to one another and see a virtual representation of everyone’s head and hands to be able to express ideas as a group. This is where the key goals of *Reality Works* come together. Design easily, anywhere, and together.

Whilst there are many different controls in the experience and some are not immediately apparent, these tools have been laid out in a way that makes it easy to quickly get started, and once users are more confident, learning additional features is only the case of pressing one extra button correctly and little else.

4.3.1 New Features Introduced to Reality Works

Reality Works began development in 2017. The research for this project took place from 2018 onwards and sought to expand on the existing framework of *Reality Works*, integrating new tools and updating processes to best assist product designers carry out their work. This research led to the investigation and implementation of the following changes/updates to the software:

- 1st person camera improvements – The first-person camera is the point of view directly from the user's eyes. Improvements to this included updating the first-person camera to fade on teleport, which was designed based on internal feedback to reduce motion sickness with less of an instantaneous jump for the user. Also, the ability to change the user scale was reintroduced. Originally, this was added as two sliders that the user could slide to scale up and down as well as move vertically up and down in height. After discussion with designers we decided to make it a simple button press for half scale, normal scale and double scale in order to make it simpler to switch between.
- Material sliders – initially users only had the option to adjust the metallic or glossiness attributes of a surface. To give the user more freedom, additional sliders for colour, saturation and vibrance were introduced. Previously, all slider attributes could only be adjusted on the PC screen, but these were then integrated into the VR space to avoid users having to step out of the headset in order to change a property and therefore breaking their workflow. These sliders were eventually removed due to too many controls over complicating the workspace but are still intended for future implementation.

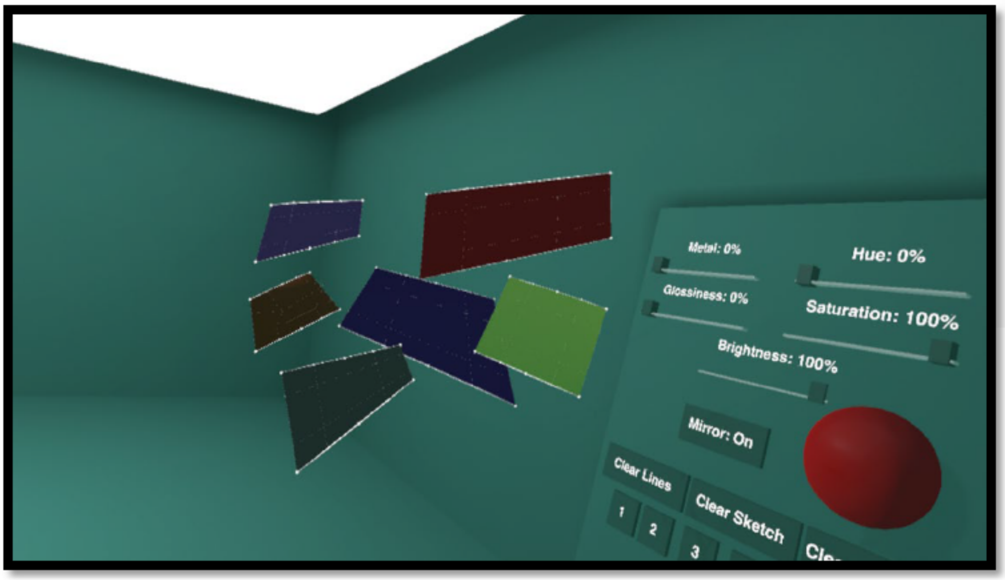

Figure 25. Material Slider Updates

- Save/load surfaces – save files were updated to also store any surfaces generated and to ensure these were loaded back in at the correct location.

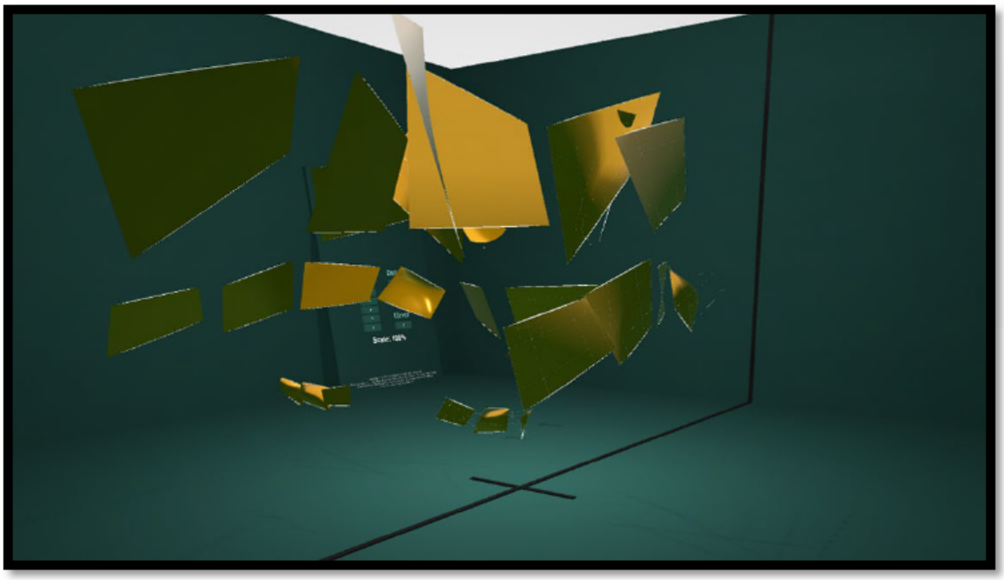

Figure 26. Surfaces Loaded from a Save File

- Mirror mode toggle – all tools in *Reality Works* work in symmetry. This allows for half a car to be designed with the other mirroring the developed side. Certain designs need to be asymmetrical however, which led to the creation of a button to toggle all tools. This became a complex process as the save/load functionality of the application had to also correctly identify which tools had been mirrored so that they were correctly loaded up in a future session.

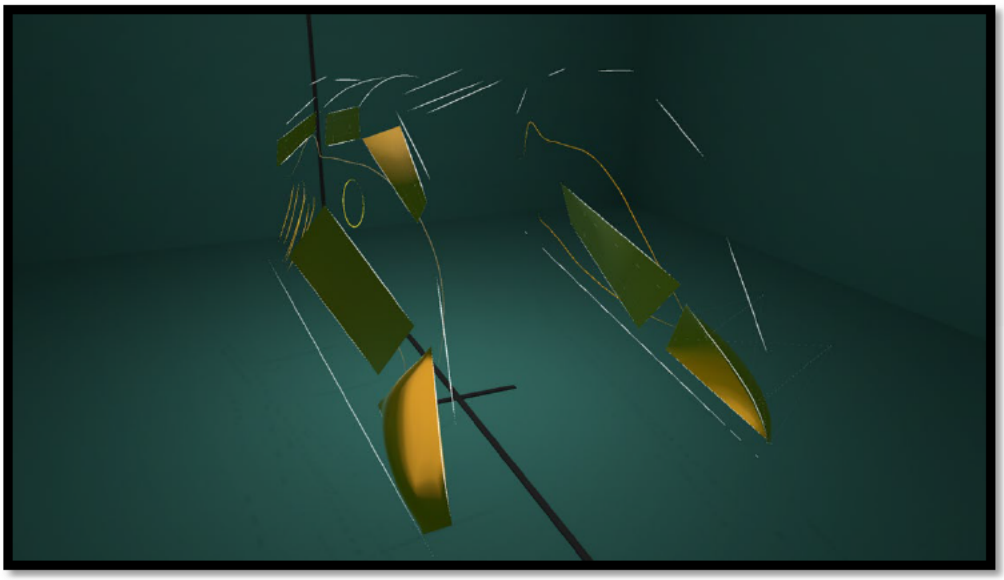

Figure 27. Mirror Mode Toggled On and Off

- Private networking sessions – the ability was added to host private networking sessions and only invite chosen people into a shared design environment.
- Networked layers – as part of the online experience, it is best for users to be able to view the same content in unison. To help with this, the various layers of geometry were networked to ensure the same content is on screen for all connected users. This functionality was implemented on a separate branch from the main *Reality Works* software but due to its success will be implemented into the main experience in the near future.

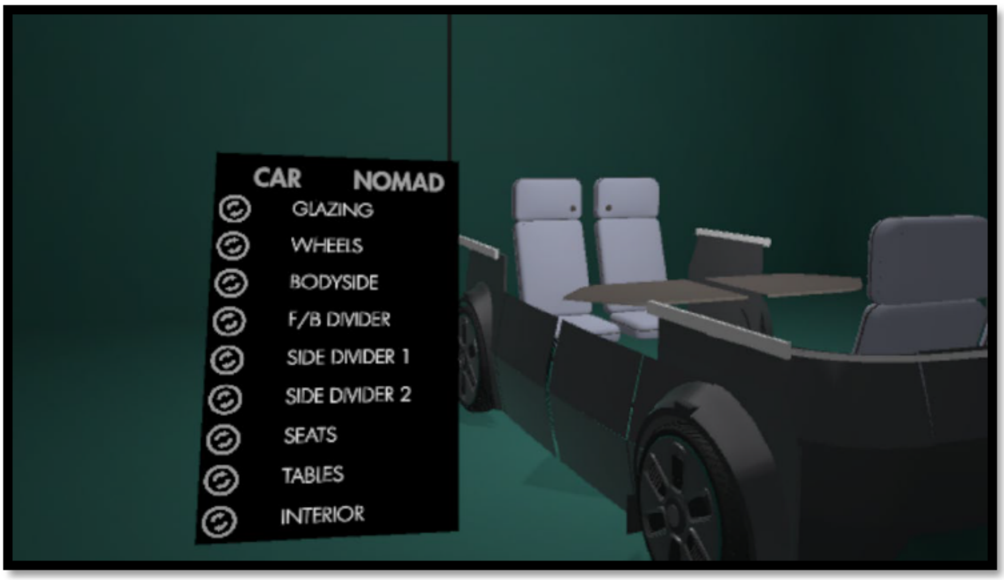

Figure 28. Menu for Selecting Networked Layers

- *Unity* version improvements – with the *Unity* game engine being constantly updated, *Reality Works* was long overdue for a backend upgrade. The software was upgraded from *Unity* 2017 to 2019. This also allowed for *Unity's High Definition Render Pipeline* to be introduced, allowing for more advanced shaders and toolsets to be integrated into the development of the software.
- Software installer – for the Beta release of the application the executable file to run the application was packaged into a standalone installer that could be sent out to interested parties instead of having to share a folder containing all necessary files.

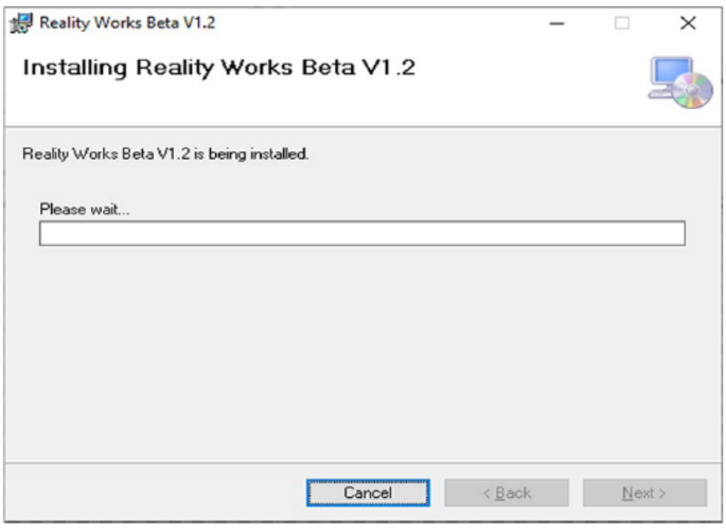

Figure 29. Reality Works Installer

These updates were built to provide more opportunity for designers. One critical update listed above was the addition of private networked sessions where users could host rooms to collaborate in. In the past *Reality Works* was always online, with all users sharing the same space. For the beta release, the networking functionality was rewritten. Users start in offline mode and can press to connect to a room if they know the passcode. Currently, only Seymourpowell have the ability to host a session, but the functionality built allows this feature to be rolled out to everyone, meaning that in future anyone will be able to start an online room and share a passcode for others to join and work together in.

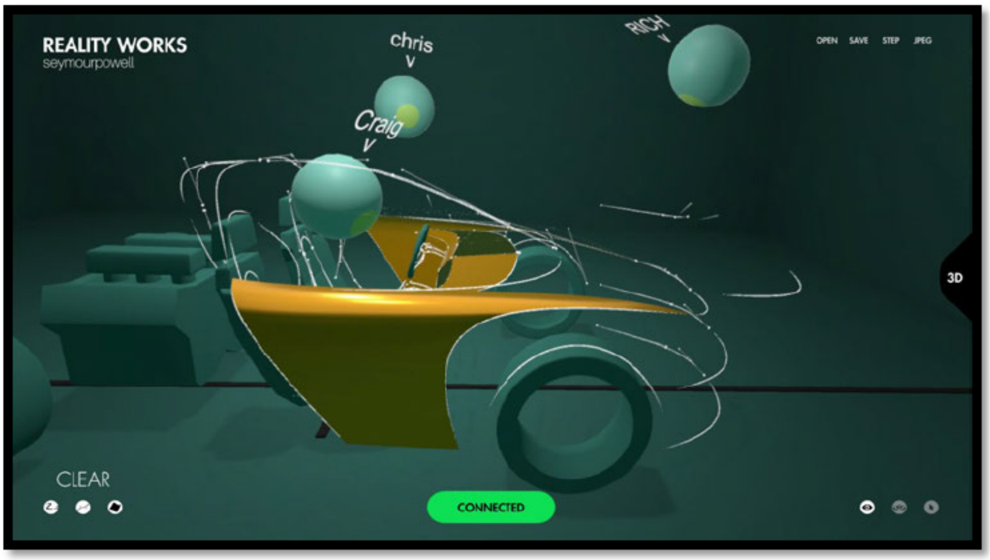

Figure 30. Seymourpowell Designers Working Collaboratively

The results chapter (Chapter 5) aims to analyse these new improvements as well as the standard toolsets in the application, to determine if the application is truly easy for a novice to pick up. Another outcome to be determined is whether this experience is fit for use in the product design pipeline. The implications of the results will determine next steps for games technology in design.

4.4 VR Camera Tool

The creation of a *VR Camera Tool* was intended as a method to improve on a director's ability to plan shots on a film set. The tool, created from the ground up as part of this research project, can be repurposed in several ways. It provides the ability to simulate outputs from real world cameras without having to purchase physical devices. Camera views can be tested and set up but in addition, renders can be planned out and product imagery can all be captured in this digital environment.

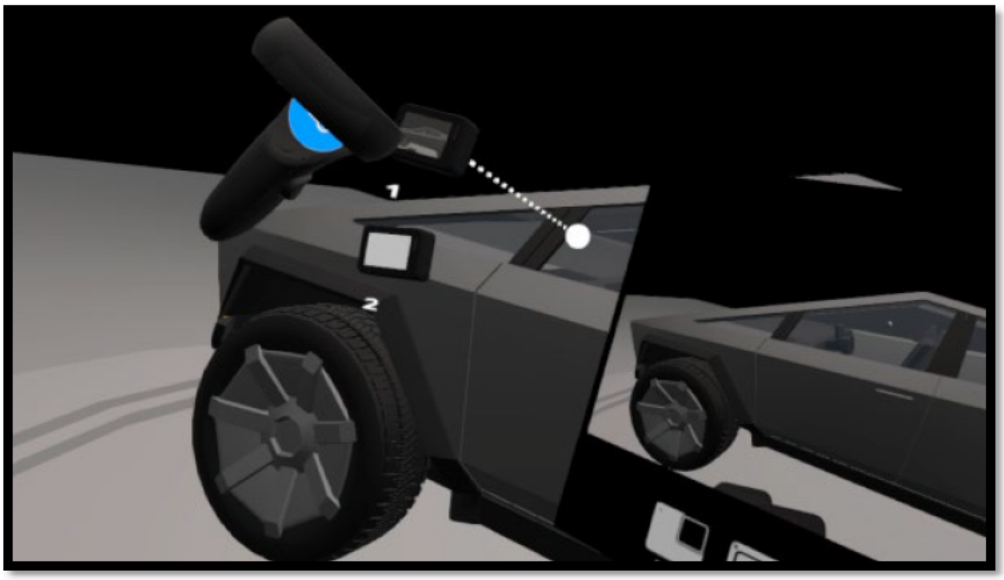

Figure 31. Positioning Cameras in VR

Users can step into the virtual environment and use the VR controllers to place and position 3D models of cameras around an area or subject of interest. Once a camera has been placed, the user can adjust its position or lens using various built in tools. This allows for the ‘perfect’ shot to be planned. Once complete the images from each camera can be captured and saved on the PC for use outside the application.

Whilst the *VR Camera Tool* was created in *Unity*, developers working on the *Unreal Engine* have recently developed a similar tool that mimics many of the feature sets implemented as part of this research. They developed a future facing film studio where cameras could be positioned anywhere. Lighting, time of day and even the physical environment could also be customised in real-time instead of being performed during postproduction (Unreal Engine, 2019). As part of their application, a VR interface allowed for the setup of virtual cameras and to even pick up and move 3D items that were part of the digital background. Their application explores some of the concepts of this research further. The main concept being that if everything is captured in 3D and is a digital asset, people should be able to enter that world and customise it as they wish. A concept explored by the recent *Lion King* film as discussed during the literature review (Chapter 2.3.4) (BBC News, 2019). Whilst the current research focused on the initial goal of being able to capture digitally what a physical camera can output, being able to manipulate lighting and the environment as discussed was a key consideration and a development that would be explored in greater detail in future. Further research on this concept was also explored in Appendix A2.

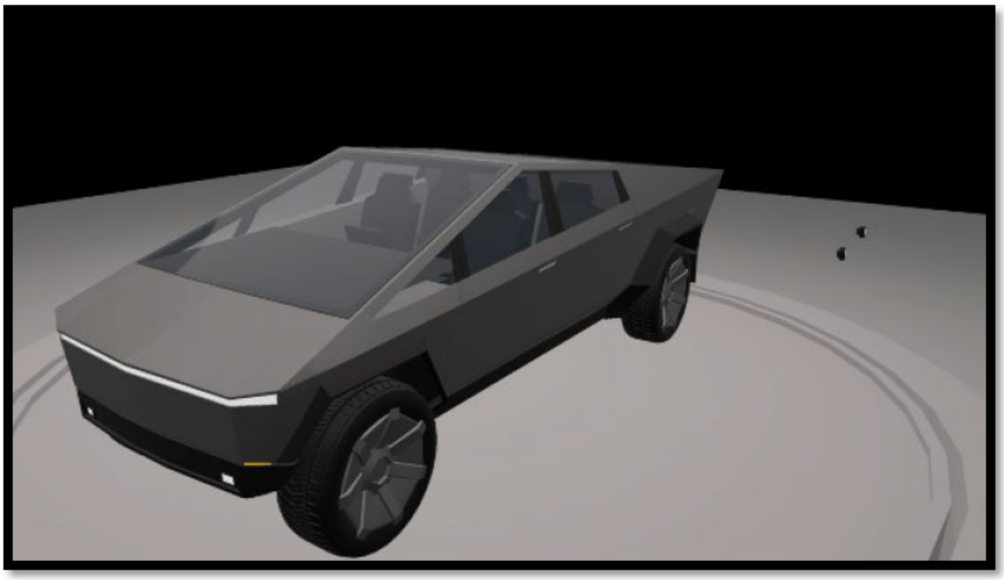

Figure 32. Overview Shot of the VR Environment

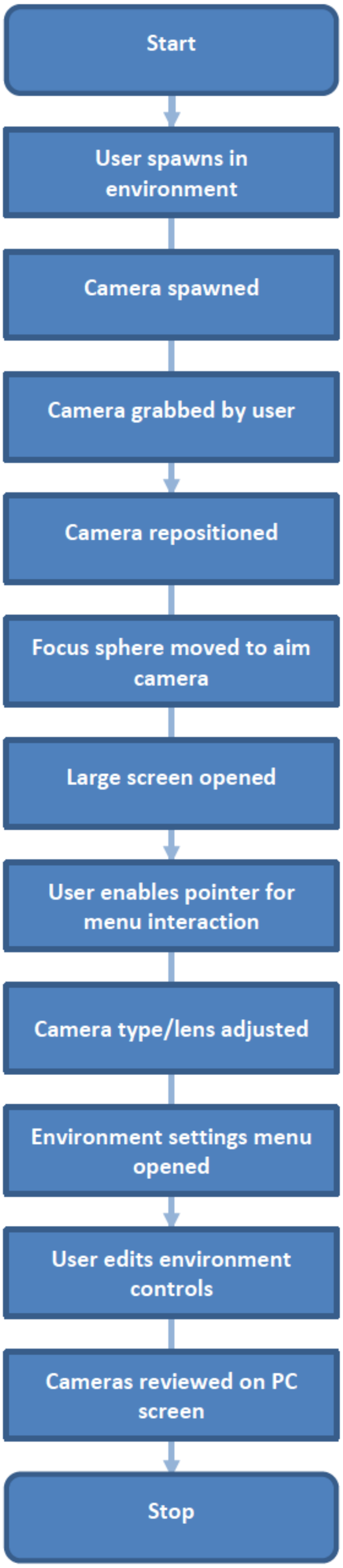

Figure 33. VR Camera Tool User Journey

The flow of the overall experience (outlined in Figure 33 above) involved the user first putting on the headset and looking around their environment. For the purpose of this research, the test environment featured a 3D model of a car. This was designed because testers would first draw a car when testing *Reality Works* before practicing how to capture renders of a developed design in this *VR Camera Tool* and therefore following some form of product design pipeline using VR. Once they had established their environment, users would press the left touchpad to spawn one of four pre-set camera types, with each quarter of the touchpad assigned to a specific camera. Each camera had a 3D model that represented the real-world size and scale of the hardware. By using the triggers these cameras could then be gripped and repositioned wherever the user desired. To capture a specific area of focus the most recently touched camera would have a focus sphere in front of its lens, dragging this to a point would cause the camera to centre its focus on this area. This could also be used to enable Depth of Field (DOF) for cameras where this was applicable.

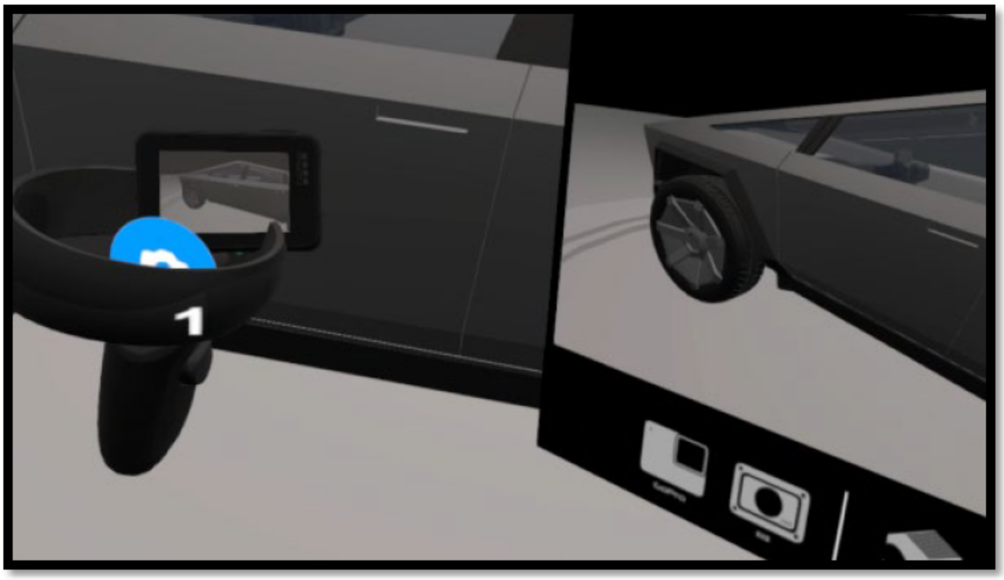

Figure 34. Looking via the Camera Display with UI Options on Right

Pressing the menu button on the left controller also brought up a large screen inside the VR room. This would showcase the viewpoint of the currently selected camera. Towards the bottom of this screen were the various camera types and lens options that could be switched between. To do this, the right controller's touchpad would enable a laser pointer that allowed for selecting on UI elements.

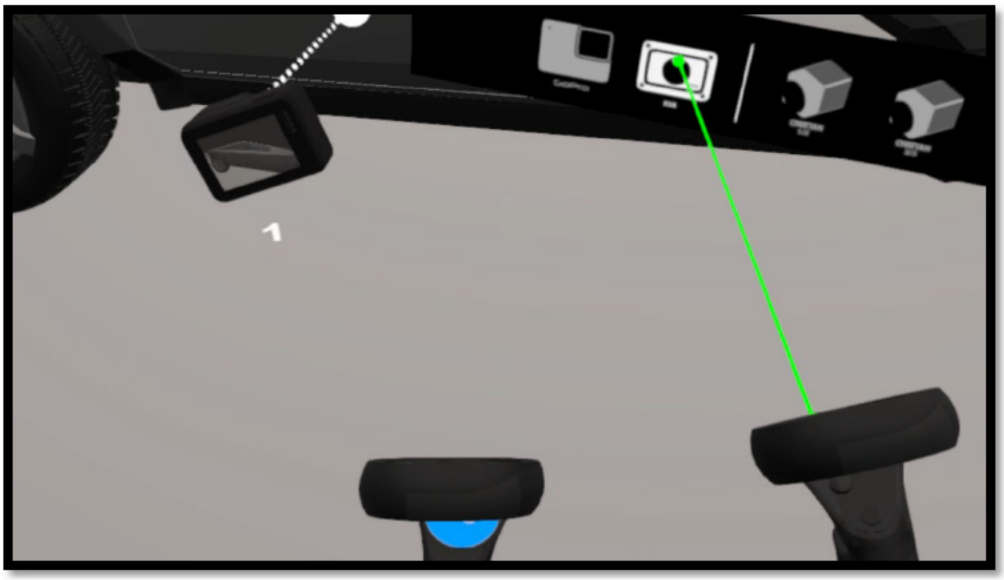

Figure 35. Laser Pointer for UI Interaction

The right controller's menu also brought up the environment control tools, allowing the user to adjust the lighting colour as well as the exposure.

Figure 36. Adjusting the Environment Settings

These elements could be used in unison to establish the perfect render or film capture point. To make navigating the space easier, a teleport tool was also introduced to allow people to more easily move around by pressing the trigger of the right controller when it was pointed at the ground, This provided the same functionality as *Reality Works* but used the right controller, due to the left controller controlling the cameras. By returning to the PC screen after being in

VR, users could cycle through each of the cameras they had positioned and save any of the views.

In the same manner as *Reality Works*, users could join a networked VR space together. Users are not however, able to see any cameras placed or edited by any user other than themselves. None of the camera models or their settings were networked as this was out of scope for this research but would be a key requirement in any future advancement.

The application pushes the boundaries in terms of production and the technology available to those that require it in associated fields. The results (Chapter 5) aim to establish if such an application is intuitive and feels as if it is a process that should be incorporated more in future works. They will also look to explore whether users believe this application could be easy for anyone to pick up, not just filmmakers and product designers.

4.5 Testing Procedure

Reality Works and the *VR Camera Tool* were put through a testing process designed to obtain data from participants from varied backgrounds. This was to ensure a blind test was carried out as participants were providing feedback on each software's usability after experiencing it for the first time. The tests were similar in nature to the methods outlined by Barnum (2010, p. 18) for carrying out small user studies. Users were defined beforehand as having no knowledge of the software, "task-based scenarios" were given as part of each test and changes were made before testing again in a second test session. In addition to being given scenarios to test in, users were encouraged to act as ad hoc testers and use the software freely within the bounds of the test. Ad hoc testing is common in the games industry and allows testers to "test the game as [they] would play it" (Bryant and Schultz, 2016, p. 269). Whilst the software was being developed for product design, it was still games software and was therefore tested as such. Participants therefore provided useful data by doing actions as they would as a typical end user.

4.5.1 Test Users

Two test sessions were carried out with the intention of refining and better establishing both *Reality Works* and the *VR Camera Tool* for future use. There were thirty participants in total. A larger group of nineteen users were used to establish an overview of how participants used each tool, with eleven different participants taking part in a narrow-focused follow up study. There was no set demographic for these sessions. Participants were university students from a range of disciplines with some users having prior experience of working in VR and others trying the technology for the first time. Each test session took place over ten to fifteen minutes per participant. The goal of the first session was to get initial impressions of using the software and to discover how easy the controls were to grasp. Participants would be given a simple task in each application, with roughly five minutes to complete this before tackling the second one. The task was designed to quickly evaluate the effectiveness of each tool, with users in *Reality Works* being tasked with drawing a car, before switching to the *VR Camera Tool* and having to take set up shots to capture hero images around a vehicle. The follow up session progressed the evaluation of each software, narrowing to specific areas. This second session focused directly on tutorials and user's ability to quickly pick up and use the key aspects of each application. By assessing if it was easy for anybody to become accustom to games technology for design purposes, it allowed for an understanding into how applications such as the ones developed could easily integrate into tasks within the world of design.

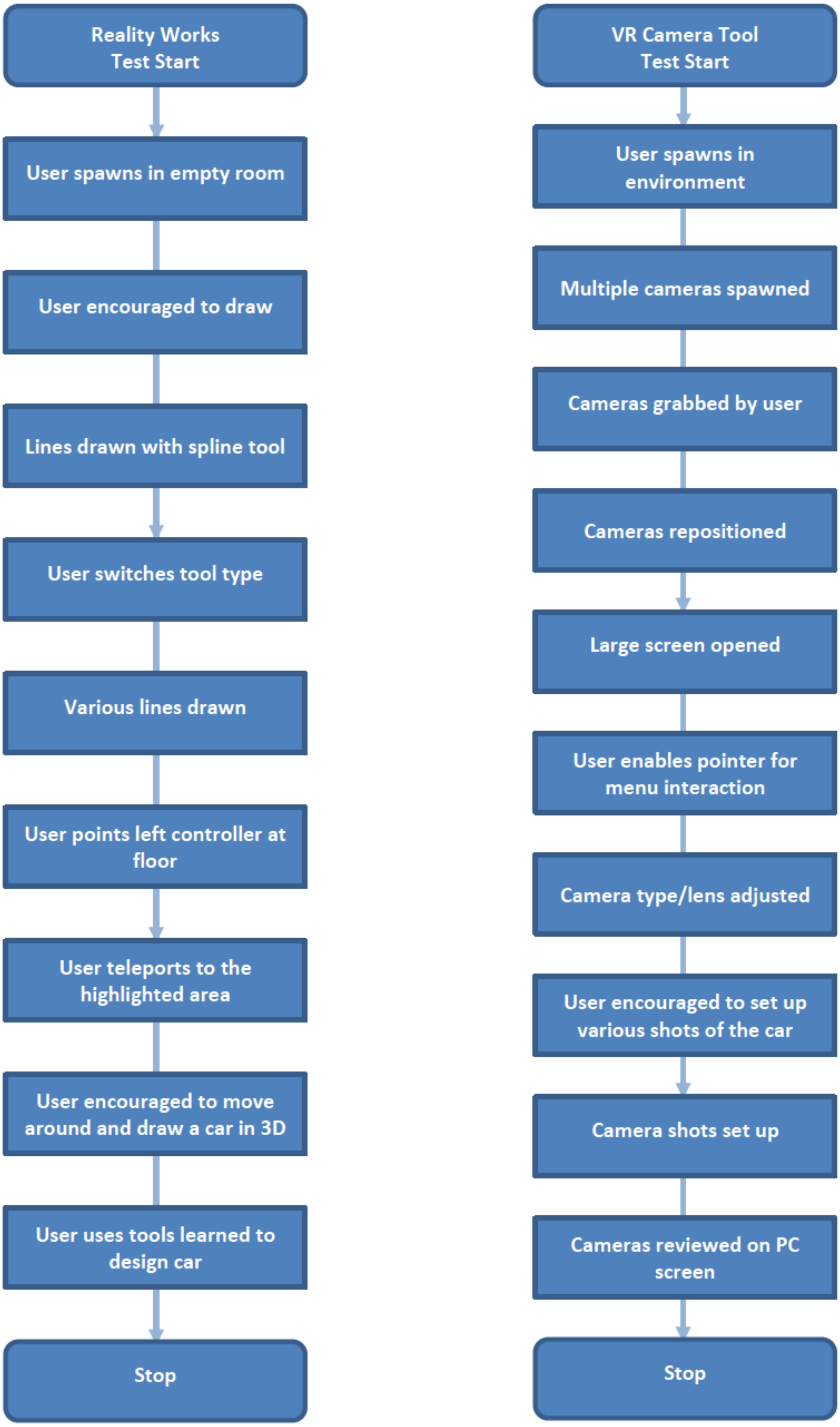

Figure 37. Example RW and VR CT Test Processes

4.5.2 Test Process

During the initial test session as outlined in Figure 37 above, test subjects were provided with an overview of the basic controls of each experience and were given a simple task to complete without prior knowledge of either application. For *Reality Works*, users were tasked with drawing a car in the time provided and they would then set up cameras to capture another vehicle in the *VR Camera Tool*. Despite being separate experiences, the test sessions were set out to have a natural flow of designing a vehicle before planning out renders of an automotive vehicle designed previously. The controls provided can be seen below, with users given a short period to review these before being placed inside the VR environment. After a short period in the first application, they were then moved on to review the second application. Once enough progress had been made inside VR, users were then given a short questionnaire to fill out to gather their thoughts on the effectiveness of the technology solutions on offer. There were various types of questions asked to participants, including simple yes or no questions to confirm whether specific features of the software were utilised and Likert scale selections determining whether users agreed or disagreed with certain aspects of each application.

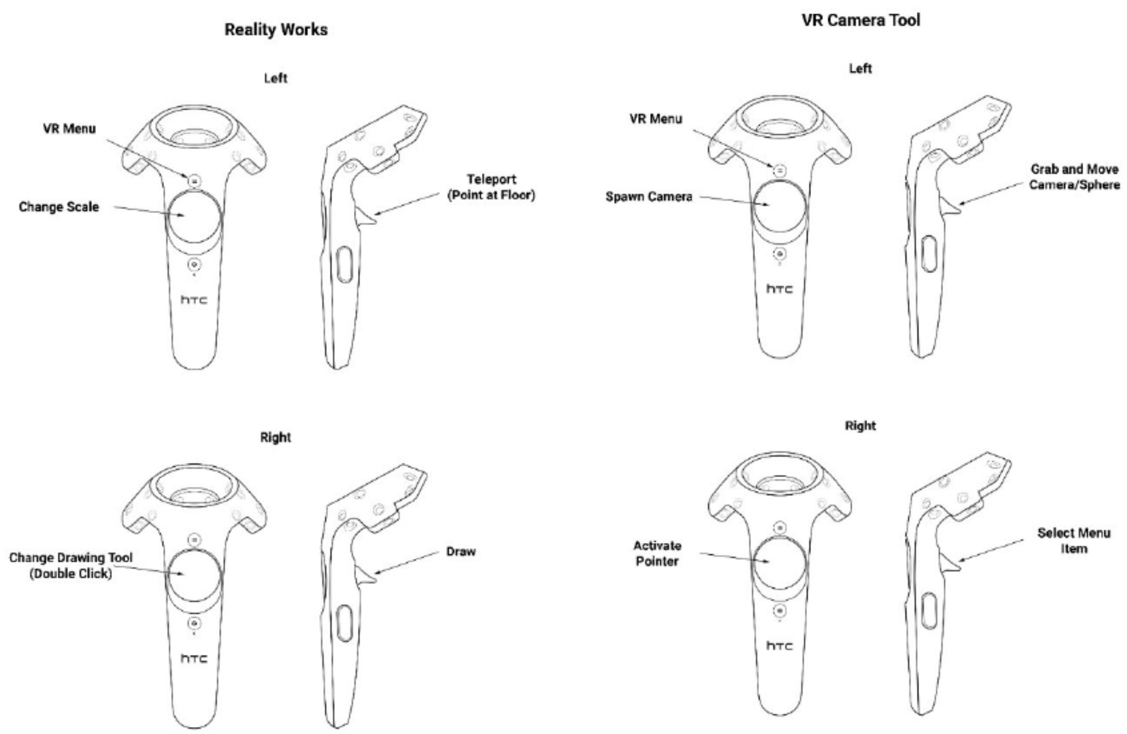

Figure 38. VR Controls for Each Application

During the second round of testing, both applications were again presented to the user with little to no information beforehand. The participants were only told to expect a sketch tool and a photography tool inside VR. This time however, users were asked to carry out simple tasks by following newly integrated tutorials in the form of prompts integrated within the user interface. Similar to the first test session, *Reality Works* users were asked to draw a car in 3D and set up camera shots of a vehicle in the *VR Camera Tool*. The new UI prompts were the focus of this test session to evaluate a participant's ability to grasp VR software quickly, therefore evaluating this technology's effectiveness in evolving a process. In *Reality Works* the draw button and teleport controls were given on screen prompts, with 3D text appearing inside VR and leader lines pointing to the button required for each control. Once the user had drawn a line the draw tutorial then swapped out for the button to change controls, progressing the user to learn more abilities. Once these simple controls were grasped, they could continue to draw at their leisure. The *VR Camera Tool* gave users guidance on how to spawn cameras in the scene as well as teleporting around. Once a camera had been spawned a prompt also appeared to bring up the review screen, a tool that users need to be familiar with to become more advanced in the software. After experimenting in both applications and completing the tutorial prompts, users were given a questionnaire to complete that obtained their thoughts and experiences on both pieces of software.

5 Results

After research was carried out into the methods in which games technology had an impact on processes and end users, various results were obtained through multiple test sessions. Approximately thirty individual prototypes were built over the course of the project for bespoke design solutions. These helped shape the two main applications of focus: *Reality Works* and the *VR Camera Tool*. These applications were scrutinised by users and refined until they contained a feature set that was practical and fit for purpose.

Each of the applications were subjected to quantitative and qualitative research through the test sessions carried out and via general comments from users. Chapter 5.1 is a summary of the results obtained from the completed tests.

5.1 Questionnaire Analysis

5.1.1 Tutorial Method

The first form of tutorial for the VR applications were in the form of annotated diagrams given to the user before they participated in the test. Despite this, it was previously believed that a better form of instruction was needed. The majority of test subjects (as shown in Figure 39) believed that on screen UI prompts would be the best method of delivering this. By taking this approach, steps and teaching for users could be planned in a set order that would allow for better knowledge and understanding of each application. Another popular choice for a tutorial was to watch another user in VR beforehand. With the multiplayer capability of each application, this could be done in real-time with a teacher and a student in VR for the most effective impact.

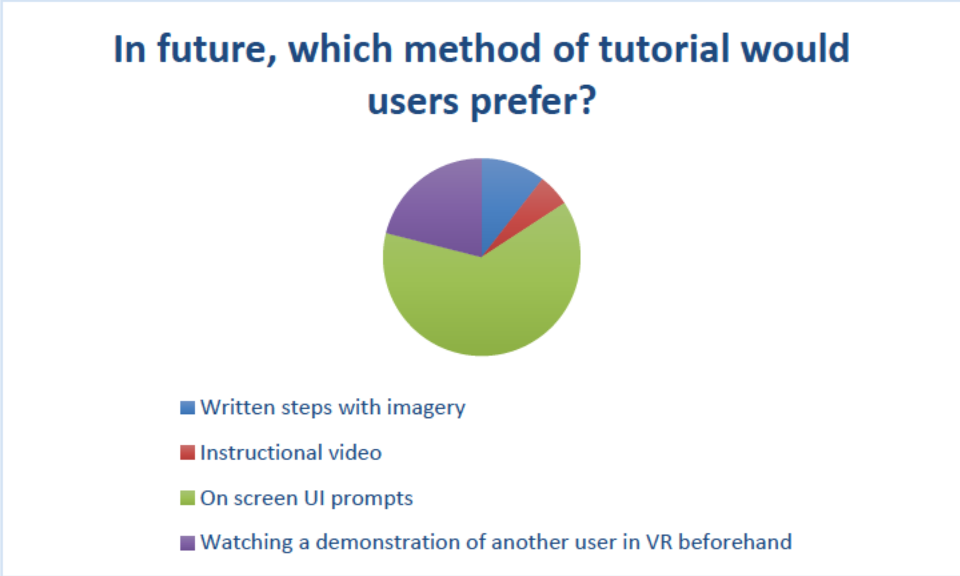

Figure 39. Tutorial Methods Preferred by Test Subjects

Based on the results obtained during the first round of testing, on screen UI prompts were chosen as the option to guide users through each application. These were implemented before the second test session to evaluate their effectiveness. The impact of this approach is analysed in detail throughout the results below, but general observations were that the users that followed the prompts found it much easier to pick up the tools inside VR than those that simply ignored all on screen messaging. To avoid overcomplicating the toolsets for the user, only a few controls (3 per application) were highlighted to ensure basic functionality could be quickly grasped. These on-screen messages were witnessed as being a positive step but could still be improved further. Locking all other controls until the one being taught is utilised or flashing the UI prompts are both methods that were under consideration. Further testing would be required to evaluate the impact of these.

5.1.2 Reality Works

The initial test results of *Reality Works* captured users' thoughts on the ease of use of the application (Figure 40). These were captured directly after the first test session to establish initial opinions on the software. Seventeen out of nineteen initial testers were able to understand the experience and learn its functionality quickly, with these seventeen agreeing that it was easy to use. From this, the research outlines that for new users, being able to quickly integrate this piece of software may not be a massive undertaking as most users can perform actions and complete tasks straight away.

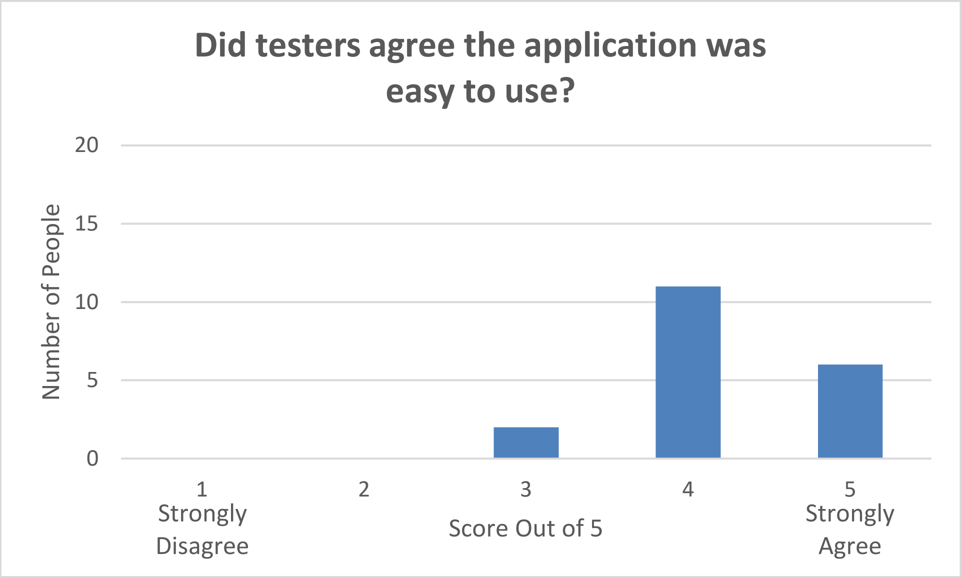

Figure 40. Ease of Use According to Testers

When focusing more closely on the controls of the experience, eighty percent of test subjects found these easy to learn. However, the results of the first test session indicated that there was less of an overall understanding of the full feature set and test subjects required additional training on how to access certain aspects of the software. Further questioning on the specific areas requiring additional training was carried out later in the first test session to better inform follow up testing. The graph below (Figure 41) shows the comparison between the controls in this first session, with the follow up session that contained UI prompts as a form of training for *Reality Works*.

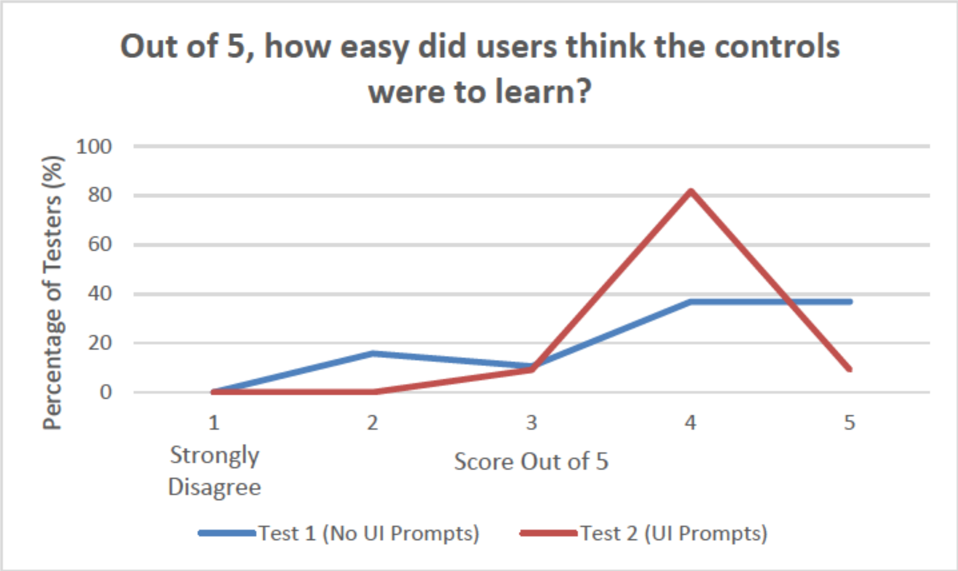

Figure 41. Simplicity of Controls for Users

Whilst the first test session had more participants that agreed the controls were easy to learn, the second session's data indicated that overall, there was less of a struggle using the tools. There were no scores on the lower ends of the spectrum compared to several in the first round of testing. Despite the varying results, testers seemed to take to the new UI prompts well, with most users having no difficulty in drawing in the application. The teleport tool was generally understood, however some users needed explaining that the controller had to be aimed at the floor. Once this was discovered participants appeared to have no issue and this initial confusion could easily be rectified through further instruction. Being able to switch tools was better interpreted than initially thought, with this rarely being an issue despite believing prior to testing that users may struggle here due to the double press of the button required. Overall participants seemed more accepting to the controls with the streamlined tutorials and simple interaction methods.

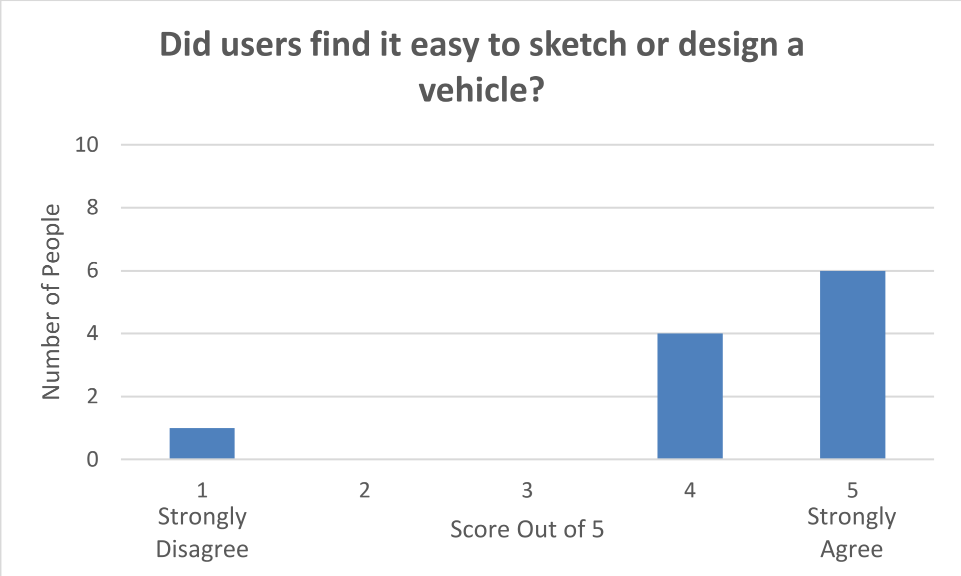

Figure 42. Ease of Sketching/Designing a Vehicle for Users

The final topic of questioning on the controls (Figure 42) focused on the task at hand, could users design a car with the application. Ten out of eleven users asked found it easy to sketch or design within *Reality Works*. It was observed that by the end of the session most users had created a car in 3D with a good resemblance to one in real life. Certain proportions were out of touch, but this is likely due to lack of design knowledge rather than an issue with the software. Features such as mirror mode, where all drawings are symmetrical aim to offset some of these issues and make it easier for everyone to design in VR. With almost everyone finding it easy to create a car, some minor tweaks and additions will hopefully make it possible for the remaining few to get on board with the technology.

The tools provided within the *Reality Works* application were designed for the common types of drawing features requested by designers.

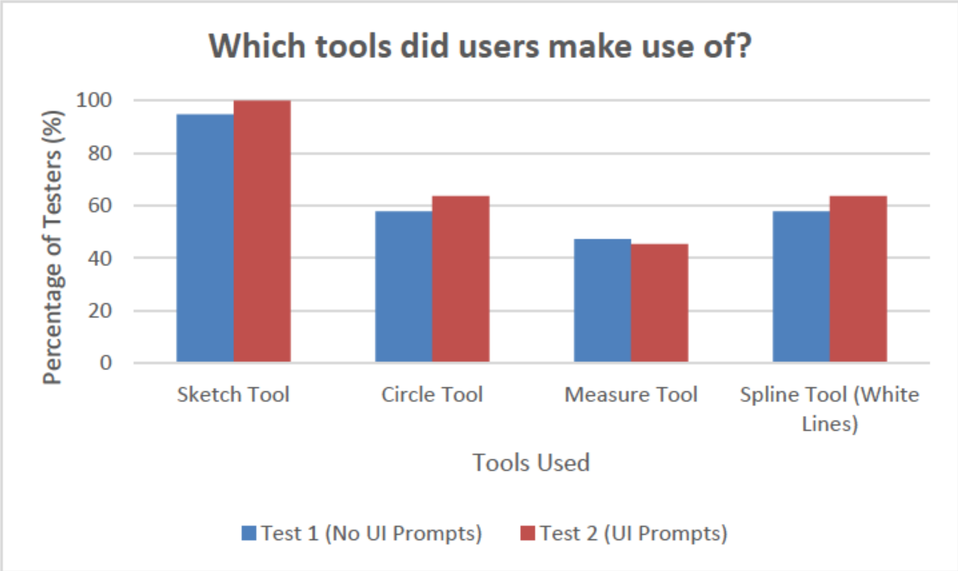

Figure 43. Tools Utilised by Test Subjects

Whilst there were almost 50% fewer testers in the second test session, the percentage use of each tool is almost identical between tests one and two. The sketch tool being the most common, closely followed by circle and spline and the measure tool placing last. These results were to be expected based on the necessity of using each control, sketching being the most common form of expressing a drawing in the software and there was little need to measure based on the given task (users were not asked to draw to scale). One notable improvement in the second session is that all eleven test subjects used the sketch tool, something that requires being able to swap from the default tool on start-up, an indication of tutorials proving successful. Another positive observation is that participants are using more than one feature instead of simply drawing out their idea, proving that additional functionality will be picked up on by individuals.

Ten out of eleven users asked in the first test session made use of the teleport functionality, effectively proving it as a method of travelling around the 3D environment that participants were able to understand. This is a key piece of data because the software can be scaled up to be used on large scale building sites or pieces of architecture and participants need to be comfortable with navigating over a larger area. To help with different sized objects, the scale function is also available however, it was only used by around 20% of those asked. This is likely due to it not being clear how to change scale and the feature not being highlighted outside of the initial control diagrams shown in the first session. As well as this, users likely need to be shown the benefits of changing scale to obtain a better perspective at larger and smaller sizes around their design. In future a prompt showcasing this would be ideal.

Once the UI prompts were added, most users were able to follow the simplicity of an on-screen tutorial that guided users through the basic *Reality Works* controls. The addition of text in the 3D space with leader lines pointing to each button was preferred over other methods. The data indicates it was successful for the most part and perhaps in future further on-screen indication such as flashing icons may help all users grasp the controls from the start.

After gaining each participant's overall impressions of *Reality Works*, the testing shifted to the benefits the technology could provide in real world use cases. Most test subjects indicated that it would more than likely speed up processes for asset creation as opposed to traditional design platforms such as CAD packages (Figure 44). Participants also found it to be an easier method of design, a key selling point for the application.

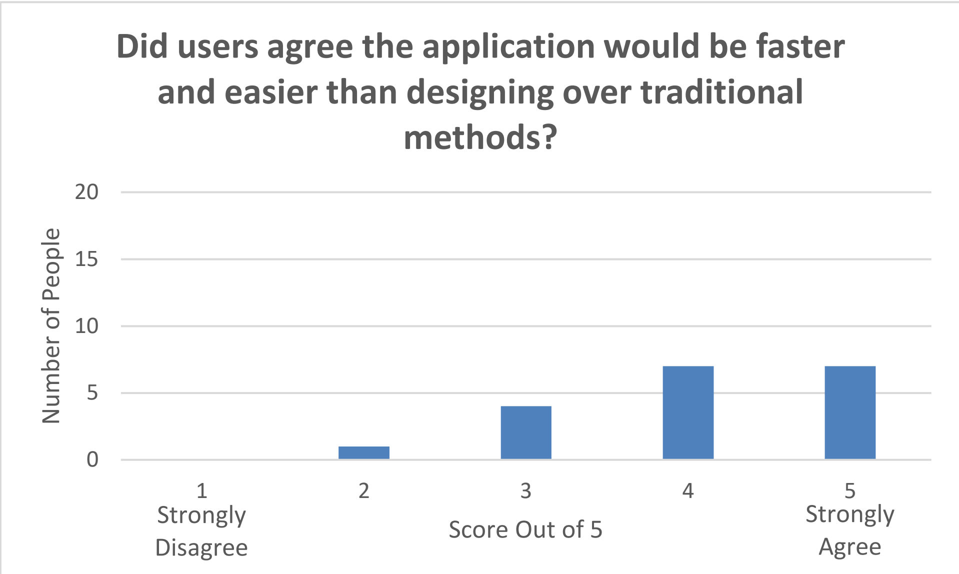

Figure 44. Did Test Subjects Think RW Could Speed Up Design?

Test subjects not only found the experience a faster and easier method over traditional design but almost ninety percent of those asked suggested that they would also use this themselves when creating assets for a digital project. This reassures the belief that the technology can help revolutionise the process in which we design, taking common games tools and integrating them in new ways.

At the end of the first test session, the overall experience test subjects had based on the data obtained was largely positive, with users feeling as if they had tried a useful piece of software that would help them design in a constructive way. The main point of contention was the lack of clarity of controls which, as outlined could be significantly improved through on-screen UI prompts. Once UI prompts had been integrated, users were again asked for their thoughts on how to improve the applications. This time they were given specific options and features to choose from. These were based on commonly used features by designers at Seymourpowell.

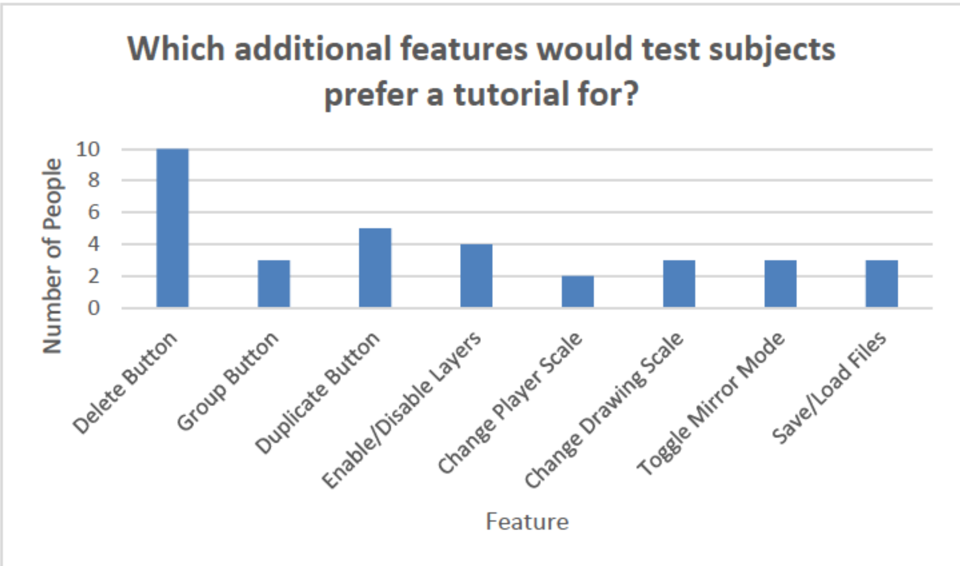

Figure 45. Additional Features Users Wanted Tutorials For

Users were asked to indicate which controls they would like to learn in future through additional tutorials (Figure 45). As expected, the delete button received an overwhelming majority of votes with several testers asking how to do this during their test session. All other tutorial requests received a similar amount of attention with the duplicate button and layer options standing out slightly. These three options that have been identified are some of the key toolsets used in traditional design software, making it apparent that participants want to be able to firstly use their current knowledge of software in this new VR environment before branching into other features such as changing the scale of their person.

The *Reality Works* tutorials implemented allowed almost all users to successfully complete the task of drawing a car without difficulty. There are some additional improvements such as making controls stand out even further so that they were noticed by all users and integrating further UI prompts that were requested. The feedback from participants was that this was a fun piece of software that some saw lots of potential in, but at least three participants still felt that instructions needed to be clearer with more indication or even an example scene to serve as an introduction to the software.

5.1.3 VR Camera Tool

The initial understanding of the *VR Camera Tool* seemed to dip slightly as opposed to *Reality Works* with the ease of use results (Figure 46) indicating that the majority did not score it as favourably. This is likely because there was a less obvious learning curve for this experience. Being able to draw is a common skill, whilst positioning camera setups is not a process everyone is familiar with. To improve the ease of use, more of an introduction to the experience was required.

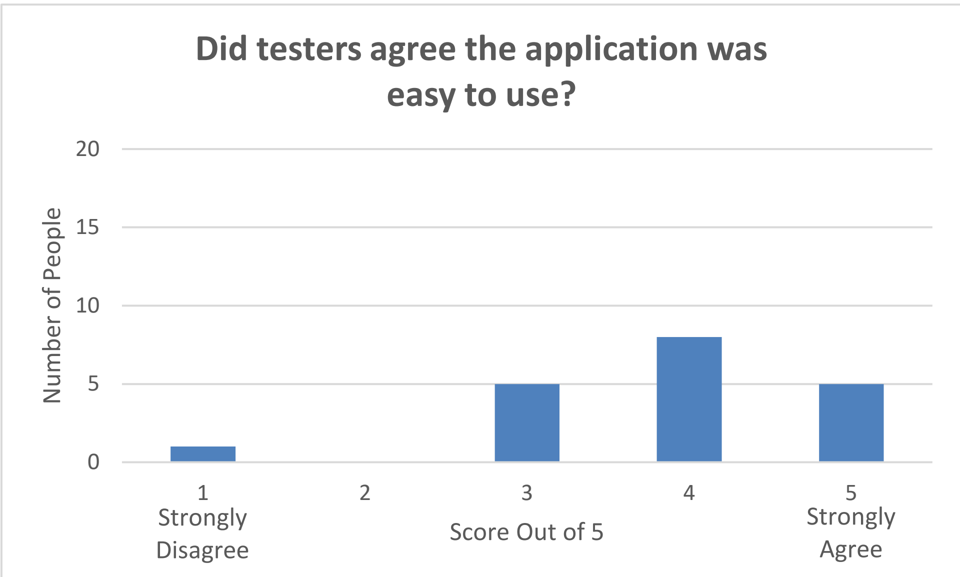

Figure 46. Ease of Use According to Testers

The controls of the software also needed to be simplified as there were multiple different input types (buttons, pointers, grab mechanics etc.) as opposed to a standardised format. Improving on this would hopefully allow for more users understanding the correct processes for carrying out operations. UI improvements were made, that led to the impact shown in Figure 47 below:

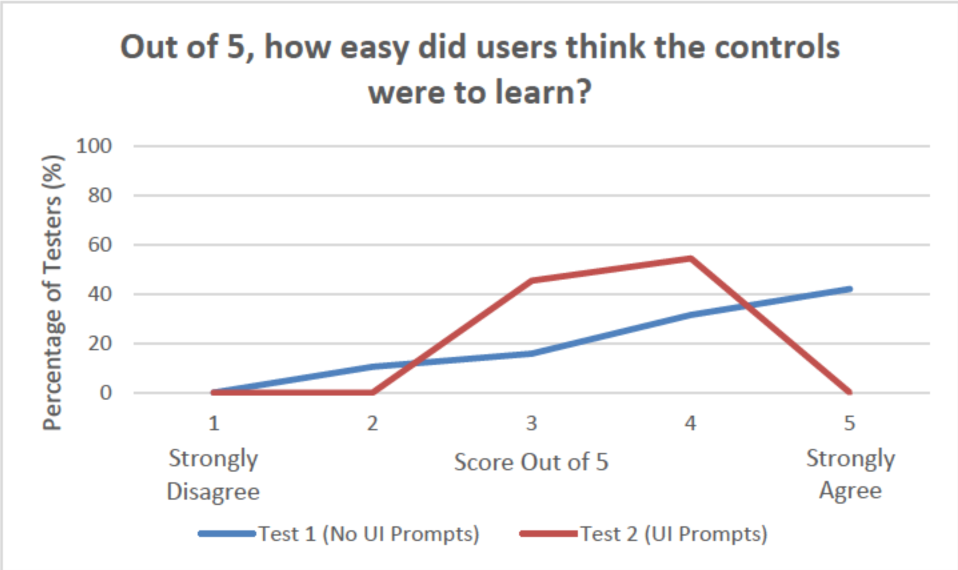

Figure 47. Simplicity of Controls for Users

After the addition of UI elements, more participants were understanding the controls, but less participants were scoring them five out of five. Whilst a positive that all test subjects found the controls to be understandable to some degree, further investigation is required to obtain higher scoring results. The main takeaway however, being that as of now participants found the tools fairly easy to use and were able to progress through the testing of the software.

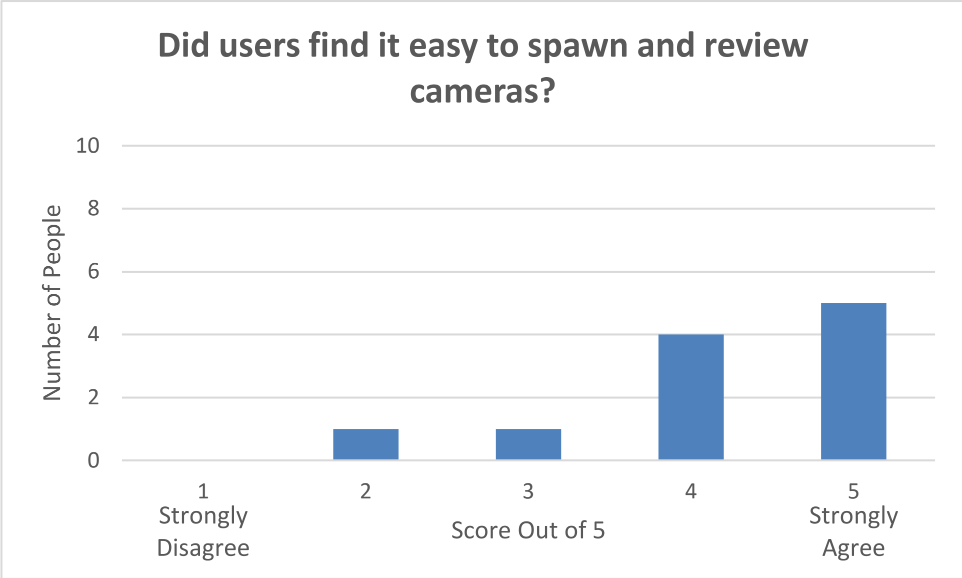

Figure 48. Ease of Spawning Cameras for Users

Regardless of the overall response from participants on the ease of use of the controls, observed throughout the second test session was that far more users managed to spawn different types of cameras and crucially use the screen inside VR to review them (Figure 48). Something that was identified in the initial test session as not occurring as frequently as intended. Now that participants are starting to utilise more of the feature sets in the software its potential is becoming more stand out. As development progresses it is hoped that anyone can step in and use complex filmmaking techniques, something participants are showing glimpses of here with fine tuning lenses and angles.

Even in the first test session, approximately seventy percent of users seemed to have no difficulty in switching cameras. This is likely due to the simple spawning functionality of the touchpad that, when noticed, was made use of frequently by test subjects. Despite this, further testing is needed as not all users utilised the customisation menu to change cameras after they were spawned. To gain a clearer depiction of lens swapping, additional data would have to be observed around this sub-area. Lenses cannot be adjusted without making use of this feature.

To adjust the angle of the camera and its focus point, the white sphere attached to each lens was well used by testers as they easily understood that moving this provided an adjustment to the camera itself. This form of interaction proved to be straight forward for users, generating an immediate response. Twelve test subjects picked up on this functionality in the first session and all users discovered it in the second group (Figure 49).

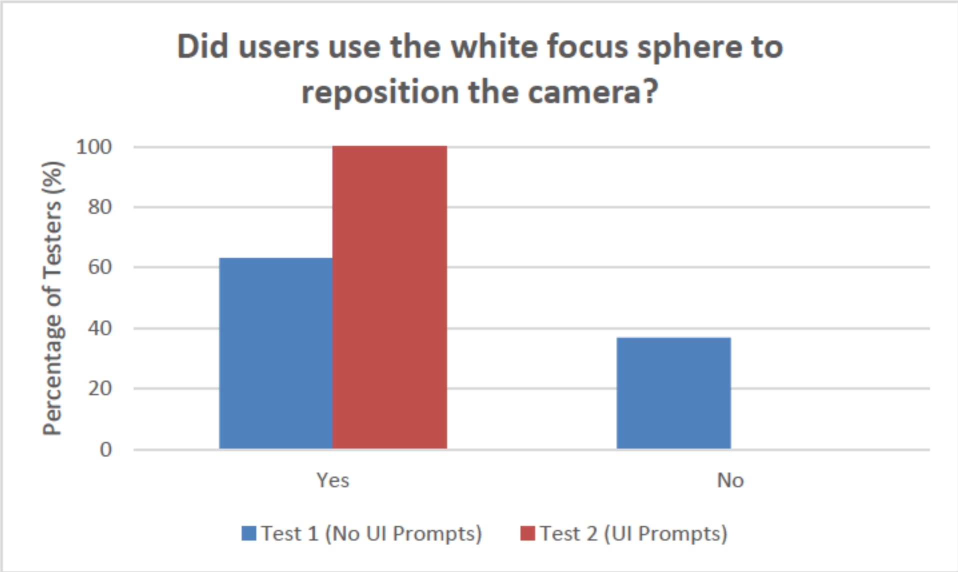

Figure 49. Did Users Manage to Reposition Cameras?

All users being able to grab the camera or attached sphere to reposition was a fantastic result as it showed that this type of interaction was acceptable for the software going forward. Participants were observed throughout easily and carefully manipulating different camera angles to capture specific shots. It also reduces the need for additional tutorials to explain this with the trigger to grab being easily recognisable by all during the test session. In future, interactions would be best suited to take a similar approach in their design.

The new teleport tool also proved effective with almost ninety percent of participants making use of it and taking advantage of being able to move around the object they were tasked with photographing. Initially identified as a key missing factor in the first test session, the teleport was a simple addition that made it much easier for participants to fully use the camera tool. Despite removing this past restriction, due to the existing controls the teleport button was on the opposite controller from *Reality Works* leading to unintentional confusion for participants. This would be less of an issue in a real-world scenario as both software packages would not be positioned together but it was still a good observation of how participants need a standardised control set. The teleport will likely be moved to the same controller as a result.

The technology of VR was proven to be a major benefit over simply making a 2D camera planning tool. Over three quarters of test subjects found that reviewing the cameras in VR to be more effective than looking at them afterwards on the PC screen. All test subjects were shown the cameras they had created on the monitor afterwards but still preferred the VR version. This result was only captured during the first test session, with the second session following the data and therefore focused on reviewing the experience entirely within VR. From the result above it seemed that the addition of being in the same space that the cameras are positioned has a desired effect for users.

The other change going from the first to second test session was the added UI prompts. These appeared to help as participants took the time to stop and read what was being highlighted to them as they progressed through the short tutorial. The main issue being that the text for each camera type was far too small that participants struggled to read it due to the resolution of the headset. This would be easily fixed in future by increasing the size of the text or using icons to represent different camera types. Despite this around two thirds of participants spawned different types of cameras as they explored the software, showcasing the feature set working as intended.

The final question (Figure 50) was whether such an application could evolve product design. The data obtained indicated and affirmed the belief that such a VR system would be an improvement over setting out multiple camera rigs in real life. Users were quick to visualise the benefit and cost saving aspects of the system instead of purchasing physical items. Test subjects also experienced the ease of setup as opposed to doing this on set as part of a live production.

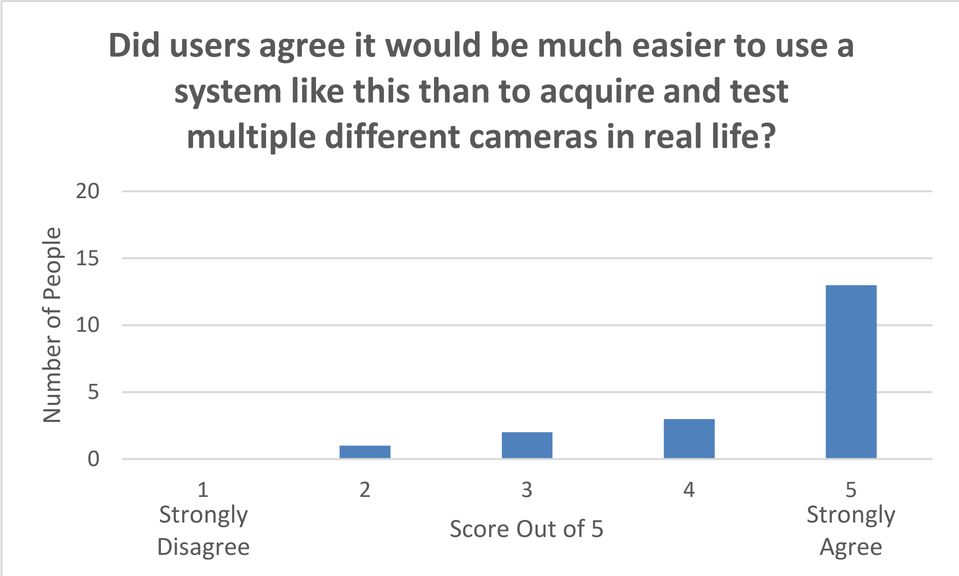

Figure 50. Testers Thoughts on Benefits Over Traditional Methods

Control difficulties aside, during initial testing around seventy percent of users found the *VR Camera Tool* to have merit in its intended use case. The main requests for additional features were again further instruction in terms of on-screen UI and a teleport feature which was overlooked at first and was then added as a prioritised update to the software. By doing this it brought the software more to life, allowing for further exploration around environments, with added abilities to capture from almost any viewpoint with any supported camera or lens.

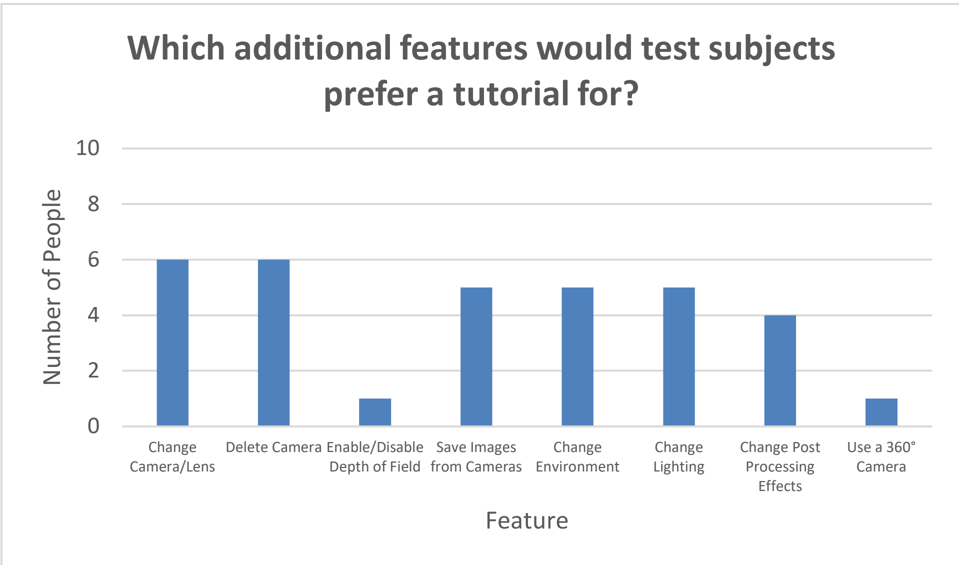

Figure 51. Additional Features Users Wanted Tutorials For

The features requested (Figure 51) for additional tutorials were more evenly spread than the results from *Reality Works* but the ability to change existing cameras/lenses or delete them entirely were the most requested. This was expected as they are logical next steps from learning how to initialise cameras in the scene. Closely following these were controls designed to change the environment or lighting which indicates that this software is successfully positioned in line with other photography/filmmaking packages with participants looking to adjust the output they capture. Again, the options available were offered for selection due to them being the most used features by designers working within the software.

The final comments and observations again pointed to the fact that participants were enjoying the experience but found this software slightly more challenging to use. With the addition of further tutorials or perhaps streamlining the control set to make it less of a leap to some of the more advanced features, participants would likely find it easier to use overall. Aside from these comments the data indicates that participants were able to jump in and use the cameras to capture footage which is the main goal initially of the software solution. As development progresses it will be more crucial to have participants understand some of the more complex operations and utilise the VR world to help participants understand things from a filmmaker’s perspective.

5.1.4 Key Takeaways

The most positive takeaway from the two rounds of user testing was that most users found it easy to learn both pieces of software, with initial controls being seemingly intuitive from the get-go. This was the case for the most common interactions, such as pulling the trigger to draw in *Reality Works* or pressing a button to spawn and move a camera using the *VR Camera Tool*. In the first session, users were shown a short diagram that covered the basics without providing a lengthy tutorial beforehand. Despite this, it became apparent that the more advanced features of both pieces of software were used far less and were more of a challenge to pick up. Whilst the testing sessions were short, it was a key goal to move participants onto some of the more unique controls and innovations of both pieces of software quickly. At the end of the session, users indicated that their preferred method of tutorial in future would be various on-screen UI prompts which would make each feature set more understandable and better showcase the range of tools available. As noted in the results above, based on the feedback from the first session, on screen UI prompts were integrated that outlined the basic controls users needed in order to use each software.

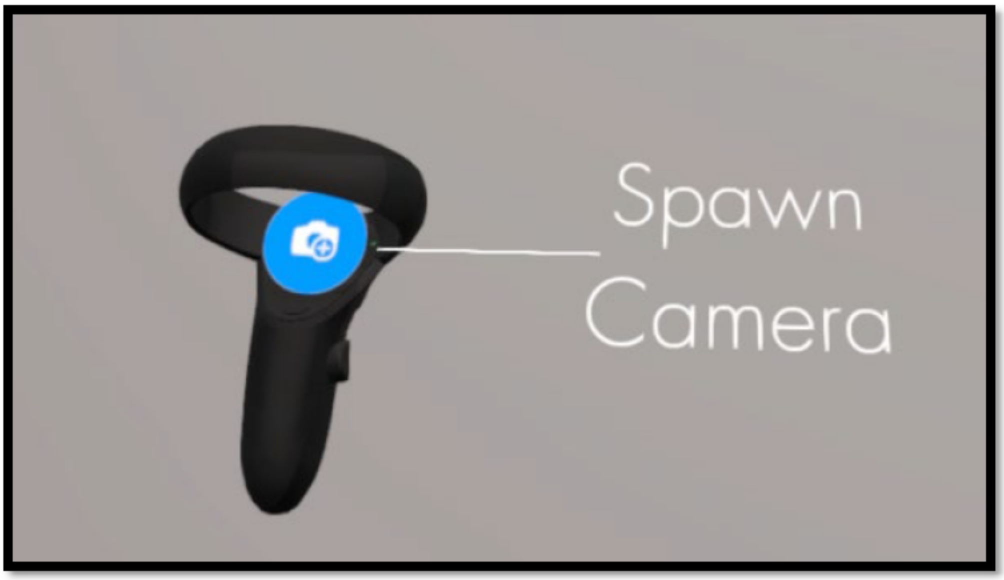

Figure 52. Example of On-Screen UI

For *Reality Works*, the draw command, teleport button and change tool button were all given UI text inside the VR headset with leader lines that pointed to each control. Similarly, the *VR Camera Tool* had tutorials on screen for spawning cameras, teleporting and for opening the menu to review a camera. An initial observation was that users that followed these prompts found it easier to grasp controls than those that ignored them all together. However, as some participants chose to ignore the commands it would be better to prevent all other actions from being accessible until a user has completed the tutorial, with the messages flashing on screen and further highlights on the buttons of the controller. Adding these aspects would prevent participants from missing out on learning the controls, enabling an increased awareness of each software. Despite this, the current tutorials were proven to be effective with the average user score for controls being easy to learn rising from 3.95 to 4 for *Reality Works*. For the *VR Camera Tool,* the response dipped slightly from 4.1 to 3.5

but this was after the teleport functionality was added in for the second test, after being a key request from the initial test session. The teleport on the *VR Camera Tool* was also on the opposite controller than *Reality Works* which users tested first, possibly leading to unnecessary confusion. Users were also asked to do more in this test session such as being encouraged to use the review screen whereas this was less critical in the first session where the focus was on simply placing cameras. Further research would be required as to whether the controls in the *VR Camera Tool* are easy to pick up, but as mentioned above forcing the user to do a tutorial in the first instance could help with this.

Despite some of the challenges to using the software at first, nearly all of those tested indicated that these applications were a significant improvement over current software on the market and that they could see the potential of these experiences assisting those in the design world. Whether it was speeding processes up, making things easier or reducing costs, the advantages became prominent to those trying out the software.

One prominent response was that the applications were fun to use, and as further discussed in Appendix B1 applications that are fun to use can increase the output of the user. For these tools to have the maximum impact on the design world, participants must not be put off by the interaction methods they offer. Controls such as teleporting or basic sketching in 3D allow participants to push the boundaries of what is physically possible using game mechanics to create and build as part of their work.

Overall, the applications were seen as being innovative for their intended end use cases, with various pieces of feedback helping to shape future development of the software. Further instruction and a better introduction to each experience is likely to ensure these applications become more commonly used. Unfortunately, due to the COVID-19 pandemic, further testing was not possible, but the initial results indicate that these applications are well on their way to enhancing aspects of the product design world.

6 Discussion

The findings concluded from the research above seek to inform the initial objectives of this research project:

i. Explore the impact that games technology has on the design process.
ii. Develop various products in which games technology assists design.
iii. Investigate how AR and VR can impact the future of the product design pipeline.

Each of these objectives provided areas of focus when best determining ways in which the games technology investigated may or may not provide an evolution to product design.

6.1 Impact of Games Technology on the Design Process

From the literature analysis and wider research into product design, it is clear there is a range of ways in which games technology is impacting the field. It has been outlined that product design is an evolving process. Moving from pen and paper, to mouse and keyboard. Innovations in CAD software and since then cloud hosted documents have allowed for new ways in which designers can develop concepts and ideas. Digital devices and online connected designs are the future, and games technology is helping make this possible.

Game engines such as *Unity* and *Unreal Engine* have turned their attention to other fields instead of focusing directly on games. With a greater interest on the automotive sector as well as the design industry in general, combined with the vast range of devices these engines can develop for, it is becoming far easier to develop in this space. AR and VR are some of the devices that are being invested in highly for the future, with billions expected to be generated and hundreds of thousands of devices sold.

As we begin to look ahead to more of these pieces of games technology (AR and VR) becoming more prevalent in society, we can identify direct methods that such devices can help bring about change in the industry. Applications such as *MeetinVR* have highlighted the importance of physical presence, being able to move around in a shared space, albeit virtually. Whether people prefer this interaction over a standard video call remains to be seen. Whilst more immersive and easier to convey emotion through pointing and expressing yourself in VR, the convenience of a standard phone call or video call may be hard to overcome. To combat this, applications such as *Microsoft Maquette* or *Gravity Sketch* showcase where technologies such as VR can enhance what has come before, providing tools for designing in 3D spaces that brings new methods to building ideas from scratch, fast. In addition, AR providing the ability to view digital representations of designs in real world space is a technological advancement that reduces manufacturing and logistical costs of physical designs. If companies are happy to embrace this solution it allows for the sharing of their designs quickly and more easily.

Whilst AR models and VR environments can influence the product design pipeline, the technology also helps other areas including the worlds of simulation and scenario testing. Being able to plan and prepare for different eventualities is just one experience users can have with games technology. Designers can also use the power of simulation to see if designs are working to their desired effect. New train system designs for example can be evaluated by train drivers before anyone is put at risk and by adding a first-person VR perspective to this it would increase the realism of testing, through a more immersive simulation. The research carried out during the case study on learning through games technology (Appendix A4) also identified that games have been used to teach and train since the 1960s and that this process is forever expanding with new solutions such as VR sports training and eye tracking solutions. Whilst all these solutions have shown promise in that they are already being used by industry, their adoption rates going forward are likely to be of interest to the entire field.

After identifying the many ways in which games technology can provide value and benefit the product design world, the applications developed through this research had a greater influence based on existing real-world products.

6.2 Products Developed to Assist Design

The results chapter (Chapter 5) looked to identify the usefulness of *Reality Works* and the *VR Camera Tool* for making life easier for the design process, whilst also making the learning curve for the new technology utilised as minimal as possible. The test process was designed to carry out simple tasks that would allow for more advanced input if the user desired. On the surface each test, designing a car in the *Reality Works* test or planning imagery of a car whilst testing the *VR Camera Tool*, highlighted what worked and what elements needed improving on within each piece of software.

The controls of *Reality Works* highlighted that for the most part the software was found to be easy to use. Whilst results fluctuated with the introduction of UI prompts in the second test, participants still scored the software highly in terms of simplicity of controls. The results indicated that adding UI prompts helped reduce the number of users that struggled with the software but may have overcomplicated certain elements such as people trying to teleport without pointing at the floor, despite being instructed to aim there before pulling the controller trigger. Showing all these initial controls at once may be too much for the user and the application may benefit from splitting up these into separate areas. It is important to remember that as product designers and people in general begin to use technology, it is an entirely new process they must learn.

The UI prompts have still proven beneficial. The next logical step would be to make the indicators for these clearer through making them flash to gather attention or forcing the user to follow the instruction before being able to do anything else. As discussed in Chapter 4.1.1, restricting access to gradually learn controls is a proven popular method in other media. Controls should also be kept consistent when possible. There was confusion between both pieces of software as *Reality Works* uses the left controller to teleport and the *VR Camera Tool* used the right. Adding a feature such as teleport with albeit the same functionality, to a slightly different button made life difficult for some participants. This was an oversight that should be addressed in future. All VR software should respect the affordances of what buttons are used for common controls such as teleport, something that could be investigated to ensure both applications get this correct.

Furthering the testing knowledge obtained from analysing the controls, success was found in making the barrier to entry for the applications as low as possible. It was intended that people should be able to pick up the software and use minimal effort to perform basic tasks. The most common interactions e.g. drawing, movement etc. were to be possible with a simple button press and not a complex menu system. Whilst complex and advanced features should still be possible in the software, the basics were taught first for people to build upon.

In both test sessions the sketch tool was found to be the most utilised drawing tool, with almost half of users switching through all the drawing tools available. Whilst it is to be expected that the drawing tool that gave the user the most control (sketch) was used the most, it was not the default drawing mode. The majority of participants were able to swap to it and make use of its functionality. Despite the sketch tool’s positive results, it was hoped that more users would make use of the spline curves to finalise their designs. Although this may be due to the fact that the test sessions were relatively short and there was no encouragement to finalise the designed product. Almost all participants surveyed about the teleport and scale tools indicated that they used teleporting, but over three quarters of those asked did not change their scale. It was encouraging that participants moved around the 3D space, but the benefits of changing scale could have been better highlighted by asking participants to draw incredibly detailed designs at small scale or a much larger item requiring the participant to be bigger. It was hoped however that more participants would use the large-scale mode to design the roof section of the car.

After testing, almost all of those asked were neutral or agreed in some regard that the design process was faster or easier using VR than traditional methods. Participants also stated that they would be likely to use such an application for this purpose in future. Whilst there is room for improvement, the data appears to indicate the beneficial nature of the product design solution being tested. The results are positive but in order to build on this success, participants also noted that having a clearer notion of how to delete or duplicate would be required in further designs. This was to be expected with copy and paste and delete being common pieces of functionality in software today. More tutorials need to be available and users should be forced to undertake the most basic ones to ensure they have some level of understanding of the software. This appears the best way going forward to help people begin to use tools like *Reality Works* for more and more design projects.

The main highlights of the testing process further confirmed the research uncovered in the literature review (Chapter 2) that convenience of technology is critical and that having the freedom to move around an environment to design in can make life easier for designers. The ability to make designs quickly as a benefit was tried and tested with cars being conceptualised in less than five minutes inside the VR software.

Testing the *VR Camera Tool* again highlighted the many positives and several negatives of the solution at hand. From the start of testing it was apparent that the control schemes were more confusing by a small number of users scoring the application on the lower end of the Likert scale. There was a difficulty for some to spawn and review cameras in the scene and whilst this may have only been for one or two participants, people having difficulty at the first hurdle indicates better communication to the user is needed to help make the software more useful. Interestingly, adjusting the cameras using the white focus sphere was an issue for almost half of the participants in the first test session, but nobody had difficulty with this in the second test session. There was no additional support given to use this between each test, indicating that more data is needed to ensure people can easily understand how to reposition cameras in the scene. Overall, whilst the majority of test subjects were observed to correctly access cameras and use them in VR, there is enough data of participants having difficulty to warrant further action in this area.

Positively, the teleport functionality added for the second test session was picked up easily by most. It highlighted that despite the confusion with *Reality Works* having teleport on the opposite controller, around ninety percent of participants were able to teleport around freely in VR. Another item that users responded overwhelmingly in one direction was the over seventy five percent of participants that preferred reviewing cameras in VR rather than on a PC screen. The VR helping designers here by providing a solution to the problem of it taking time to step out and review work on a desktop screen. Instant feedback can save time and effort, which is likely what participants based their preference on.

Only one user disagreed that such a system would provide an improvement on what currently exists, buying lots of cameras and trying them out physically. The VR may have to do more to replicate this experience to convince everyone but the majority of users seeing the benefit in this technology further indicates its ease of use. Most test participants were unlikely to have experience in film directing but could still see the benefits of the *VR Camera Tool*. With major film studios such as Disney in the *Lion King* making use of similar software a real ambition to kick start technology in this field is clearly there.

The *VR Camera Tool* in particular needs more in the way of instruction. There was a much more varied response in the testing of this compared to *Reality Works*. Almost all the additional tutorials suggested were wanted to some degree, with little separation between items such as changing cameras, deleting cameras or even changing the environment. There is so much going on in this piece of software but as participants are less likely to have come across design tools aimed at marketing departments or film directors, perhaps further information on why the *VR Camera Tool* is powerful needs to be outlined. *Reality Works* made sense as everyone has experience drawing and can understand how this is a natural skill for designers. People understand what a camera can be used for but when it comes to choosing between various lenses and models, without the technical background it may be difficult to decide. However, the methods of the testing process meant that little information about the software was communicated beforehand to observe as much of participants first impressions as possible.

In terms of initial changes that need to be made, much like *Reality Works* there needs to be an improvement on the already helpful UI prompts. With teleporting, laser UI pointers, touchpads with multiple selections and in game menus, there needs to be a clear and concise way of introducing these to the user. Other small updates include being able to save rendered images from inside VR instead of stepping out of the experience to do this on screen. This is based on people preferring to review images in VR. All these additions are small steps that would increase the software's ability to save time and money which, as identified, are key methods that highlight the success of technology.

6.3 How AR and VR Can Impact the Product Design Pipeline

AR and VR provide the opportunity to save time and money, something that has driven organisational change throughout history. Sketching in VR for example has made it easier to visualise concepts and test them in a virtual environment. The need for the sketchpad is minimised and can even be removed altogether, people can simply just start drawing and bring ideas to life. Removing parts of the standard pipeline allows for certain aspects to be sped up. More design iterations are possible as fewer physical prototypes are required. A car design can be evaluated without ever being built beforehand, with the entire team standing around and even 'sitting in' the virtual vehicle. Collaboration tools are become more and more prevalent. People do not have to travel the world, taking up time and resource, when digital content can be viewed almost anywhere. Designers can have a blank but interactive canvas. Tools can be built to recreate almost any real-world process, but these can be enhanced with new customisation techniques. Being able to produce an entire movie or structure a product line from the comfort of everyone's home is something that is now possible with the advances in games technology.

Whilst there are still some issues to be solved, including data conversion and people's general reluctance to change, as time goes on more and more people are likely to begin embracing technology as they have done in the past. AR and VR may not be able to change the world of product design overnight, but they can begin to bring about change in a positive light.

Based on the results gathered it was also established that people look for new innovations to first educate them on processes they are already familiar with. Designers want to learn how to carry out tasks they would use day in day out on a desktop machine before experimenting with any unique tools exclusive to this advancement of technology. People want to understand how to copy/paste or delete in a new piece of software so they can achieve the same result as their current output before they begin to experiment with new methods of approach. When learning how to use software it was also noted how fun affects performance. Through observations in testing people had a more positive interaction with the tools developed when they were less stressed and confused and enjoying themselves. Being able to place cameras from inside a car that did not exist in real life yet was entertaining for several users, making them more responsive to the new toolsets on offer.

At this current moment *Reality Works* and the *VR Camera Tool* are at a point where they can begin to help designers and everyday people accomplish tasks in new ways. Whilst there is plenty of room for expansion on their capabilities, their current feature sets already provide a step up for the world of design. *Reality Works* currently allows people to 'step in' to the virtual environment to draw out designs, before refining these with precision spline, exact circle and measuring tools, allowing for a quick concept to be created. The ability to import model data from a PC to use as a base and being able to mirror whatever is being drawn are some of the toolsets that give designers a step up. As designers begin to learn more about the software, they will begin to learn more about, grouping, duplicating and spawning 3D surfaces to further bring their ideas to life. With these skills and being able to collaborate with others in a shared space, it is immediately obvious to users how helpful such a feature set is to the everyday designer. The *VR Camera Tool* is another example of complex functionality that can be stripped back to functionality that immediately helps users accomplish tasks in a better way. Set designers, photographers, directors and more can quickly position virtual cameras and save their output. This allows them to quickly arrive at conclusions over how best to capture content. In addition to spawning and saving content easily, advanced features such as selecting specific lens types and modifying depth of field are again key features, but not specifically required by all. These two applications in combination with further prototypes developed have provided clear insights into the ways in which games technology can help shape the design world. It is clear the advantages of AR, VR and other future facing hardware, can be put into practice to meet the demand of the product design world. This can allow this industry to achieve new heights and enhance many processes.

All this links back to the Bauhaus style of thinking, minimalist design that served a purpose. Each of the tools developed were built to help and assist processes, whilst doing this as simply as possible. These tools could be the next big evolution, just like computers and CAD packages evolved traditional drawing practices. The research carried out has shown different parts of the product design pipeline that can be assisted through games technology. Whether it is the initial stages of coming up with ideas and planning these out, to refining an idea, or even through testing by applying technology such as eye tracking to understand user preferences. *Reality Works* and the *VR Camera Tool* as well as all the different platforms out there provide support to the current product design pipeline, and it is up to each designer to determine how much these platforms support or replace existing practices going forward.

It is not the goal of this research to fully replace existing practices, concept cars still have to be manufactured, hardware still has to be built to assess its validity and there are cases where people will still have to travel to evaluate work. Games technology cannot completely rewrite the book on how to design, but the latest developments serve as a step up on what has come before.

The results and research so far have concluded that the work carried out can be effective to an extent in the evolution of design. Despite this more can still be done to assist and improve on existing practices.

7 Ethical Issues/Conflicts of Interest

Due to testing with human participants, ethical approval was acquired prior to testing. An ethical approval certificate can be found at Appendix C1.

As mentioned throughout, this research is supported by Seymourpowell, which the research participant has been working with throughout. Despite this, the research is only of interest to Seymourpowell and they had no influence on lines of enquiry and the specific research undertaken. Work was carried out over the course of the project with Seymourpowell but only that which is relevant to this research is included in this report.

8 Conclusion

The research carried out aimed to provide avenues in which games technology could assist in evolving the design world. The games technology described has been outlined as a series of hardware and software that can be applied to other industries than simply entertainment and video games. To approach the possibility of such technology benefiting product design, an understanding was first developed of the history of design and how product categories and concepts have been established in the past. This led to research on the Bauhaus and the belief that design must serve a purpose, which became a key approach for this research. Once the past principles of design had been explored, focus was shifted to current product design pipelines and the process designers worldwide go through on a regular basis. This helped establish ways in which games technology could support and provided an insight into how best tools could enhance the product design pipeline. An insight was established in particular into Augmented and Virtual Reality, with the new functionalities these solutions brought to the table. By researching and having prior knowledge of these devices, they served as key areas of focus for developing products to assist design.

Once the main areas of technology had been established, applications were added to or developed from scratch to be used in evaluating technology assisting design. Seymourpowell had previously created their platform *Reality Works* and features were added to this to explore types of content that may be beneficial to designers. The *VR Camera Tool* was also developed as a second piece of software that could be analysed. These applications benefited from influence via experimental prototyping of games technology and research from several case studies carried out. It was clear through these case studies that such technology is already beginning to impact the product design landscape. The research explored many different technology offerings in AR, VR as well as investigating how best to teach people to use these devices and this led to the realisation that games technology has been assisting the world outside of games for years. Both *Reality Works* and the *VR Camera Tool* software provided new ways to design, and the resultant quantitative research captured the impact such software could have on the wider product design pipeline.

The results were clear that users found these software solutions beneficial and could provide cost saving, time saving or even preferred methods for design. *Reality Works* was seen as a platform that made a significant impact on how concepts can be developed through its use of drawing tools and simplistic controls. The *VR Camera Tool* again looked to provide quick and easy solutions to complex processes by making filmmaking and production setups as straight forward as pressing a few buttons on a controller. Being able to edit a scene or movie from inside the virtual environment is an entirely new concept and one that could be powerful for many industries going forward. Despite both pieces of software needing further instructions for users, the simplicity of UI prompts for the user was seen as an optimal method for getting people designing as quickly as possible, whilst minimising confusion of a new platform. Whilst there were many influences of games technology in the wider business world uncovered, the research of this project is simply providing an insight into what is currently happening in the design world and what could be next.

Product design as a process will always involve taking ideas and making them a reality, but the approach and methods used to do this will continue to improve as technology itself evolves.

9 Future Work

After analysing the results and observing test participants, there were several areas in which the software could be improved going forward. To determine the best way to make improvements however, further research into the best method of implementation would be required. It is the hope that if researched correctly, such improvements would help integrate the applications into the design world by providing additional support or useful features.

Reality Works is already at a point where it is being used in industry, with Seymourpowell often using it as part of their design pipeline. It's ability to quickly bring ideas to life is invaluable for designers but the software lacks many features found in a traditional CAD package. In future it would be highly valuable to begin integrating common features of CAD packages such as being able to draw many primitive shapes before editing specific points of these quickly. To determine the best elements of CAD packages to integrate would require the interviewing of various designers to highlight key features needed. One element likely to be requested would be functionality to turn on and off components of a design. There are already layers inside the software for turning on/off 3D data, but this could be expanded to turning on and off parts of sketches or drawings.

When working with geometry created outside *Reality Works*, the software currently supports .obj files but the import feature would have to be expanded to support all types of model files to make it more suitable for industry. Each additional file type supported would require development and robust testing. Perhaps identifying the most popular files used by designers would be a better approach than to aim to integrate many different file formats. Another issue for designers is that as wireless headsets such as the *Oculus Quest* begin to dominate the market more, they will need a way of exchanging data between a separate headset and PC easily. All of these features not only need built into the software but will also need taught to users. Further quantitative data will need captured to explore the best methods for this.

There is also further research that would be of benefit to development of the *VR Camera Tool*. Whilst powerful, the *VR Camera Tool* at present feels very specific in its use cases. The software provides a glimpse into how filmmaking and photography can improve in the near future, but the revolutionary aspect of this software needs to fit more industries to give it mass appeal. If the software can become more of a storyboarding app like those researched, it will enable its capabilities to be suitable for many more individuals and organisations. This would be quite the expansion to the existing software and would need to be carefully planned and studied to be executed correctly.

At present the camera production capabilities are powerful but limited. The goal would be to turn this into a tool where animations, photography, motion capture sequences or even entire movies can be planned out and filmed from within VR. While this is a long way off, the results of the current state of the application showcase that there is merit in what it already achieves. In order to achieve these new features, just as *Reality Works* has had input from designers themselves, those in filmmaking or similar fields would be able to influence the best way to implement these suggested additions. The ability to test potentially millions of pounds worth of equipment without even picking up the physical camera hardware makes a very compelling argument for how production should be carried out in the future.

With these changes alongside the greater goal to make this powerful tool applicable to more projects, the *VR Camera Tool* will be even more likely to showcase how games technology can evolve existing processes.

Further investigation is needed into the optimal methods for getting product designers to begin using software such as *Reality Works*, the *VR Camera Tool* and other technology explored through this research. Currently the data has outlined that integrating tutorials and introducing concepts can be a slow process and finding the best method can take multiple attempts. Despite this, this project has shown that design is constantly evolving, and technology still has new exciting ways to better the process.

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13 Appendices

Appendix A – Case Studies

Appendix A.1: VR for Concept Design

Innovation Title	VR Design	**Available Since**	2016 (Tilt Brush – *First Example in Modern VR Era*)	**Hardware Options**	HTC Vive, Oculus, Windows MR, Valve Index
Games Technology Utilised	6DoF, Virtual Reality				
Industry Uses	Architecture, Engineering, Design, Product Design				

Innovation Overview

With Virtual Reality (VR) reappearing in the technology landscape in the past decade, new software solutions to everyday tasks came along with it. Before long, most industries had at least one provider exploring the option of using headsets to benefit their output. The real innovation was the advancement from 3DoF (Degrees of Freedom) where users had to stand still and watch 360° images/videos happen around them, to 6DoF that allows people to fully walk around inside an environment. The design industry, and in particular product design saw an opportunity to utilise this 3D space as a way of reviewing concepts and before long there were various platforms on offer for fully designing within a 3D environment.

VR for concept design builds on games technology to allow designers to conceptualise, iterate and build new products, whilst using their physical presence to evaluate the space around them. Users are dropped into a blank

3D canvas where, at the most basic level, they can draw just as they would on a piece of paper, except with 3D depth. From this, designers can begin to trace out entire products and visualise ideas for the first time. Additional tool sets seen in various VR sketching programs expand on this by offering 3D shapes, different lighting environments for evaluation and even the ability to animate creations (Rasmussen, 2018).

VR design has helped vastly increase the production and evaluation of content. This is why major firms are establishing themselves in this space. *Gravity Sketch* (Gravity Sketch, 2017) and *Microsoft Maquette* (Microsoft, 2018) have demonstrated some of the new ways in which VR modeling and simulation can change the game.

The underlying technology makes it possible to bring realistic 3D models into the space for evaluation and is of profound benefit for product design teams. The software allows designers to validate their ideas early in the project life cycle. In a matter of minutes users can evaluate design decisions that could take far longer to identify on a computer screen or from running a simulation. When designing a car for example, the vehicle must meet international standards for bumper and bonnet height. It must be compatible with different traffic light heights and these conditions must be met for each set of lighting regulations in the territories the car is intended for. VR allows the designer to load in these hard points of data to make sure the design conforms. All without leaving the office. Designers can also work much more closely with engineering teams by integrating their crash and drivetrain packages from the very beginning of the design process, often eliminating iteration steps by avoiding clashes and miscommunication.

VR design enables the creation of whatever people can think of, without forcing new methods upon the user. It is not a tool created to remove traditional practices, but instead the creativity VR brings enhances traditional methods in new and exciting ways.

Impacts on Design

Design today is rarely carried out without the use of a computer, despite the visual technology only becoming predominant in the past twenty years. In moving to computers, the design world discovered new ways of carrying out tasks. Computer-Aided Design (CAD) software was introduced and this reshaped the design landscape (Richards, 1985), allowing for concepts to be built entirely onscreen. The technology has now been adopted worldwide by over nineteen million users and is considered the cornerstone of modern design (Livingston, 2012). Virtual Reality (VR) has the potential to reshape the design industry in a similar way in the near future. The idea of quickly sketching out an idea has gone from pencil and paper, to a 2D screen for digital sketches, to a full 3D environment that can spawn creativity.

Despite evolving the methodology, the process has remained constant over the course of product design history. The traditional design process of the past century has involved refining and evolving an idea, through various brainstorming methods and discussions, sketching, and drafting until a physical product materialises (Tayal, 2013). Once this process is complete, it is repeated until the final design is agreed upon. VR interaction not only speeds this up, but also enhances, the overall design process.

Gravity Sketch (Gravity Sketch, 2017), one of the first pieces of modern VR design software available, is a key player in the field. Launched in 2017, the software supports all major VR headset providers and is available for anyone to purchase. Aside from sketching in 3D, the software supports tools common to traditional CAD packages with scale, move and rotate options all accessible from a VR controller. Other features such as data importing, and screenshot capturing make it simple for users to import ideas and export solutions. Similarly, *The Wild* (Wild Technology, 2019) allows for concept design in VR, with the unique approach of starting at a tabletop sized environment that people can walk around before being shrunk down to a 1:1 scale of the full environment. This feature allows for the review of a full building, city, or landscape etc. quickly without being constricted to physical world sizes.

The various packages on offer for designing within VR are already having an impact on the design world, with hundreds of thousands of copies sold so far (Steam Spy, 2020). The ease of access and simplicity they provide welcome them to the design pipeline without the need for excessive training as people can get started simply by putting on the headset and pressing a button.

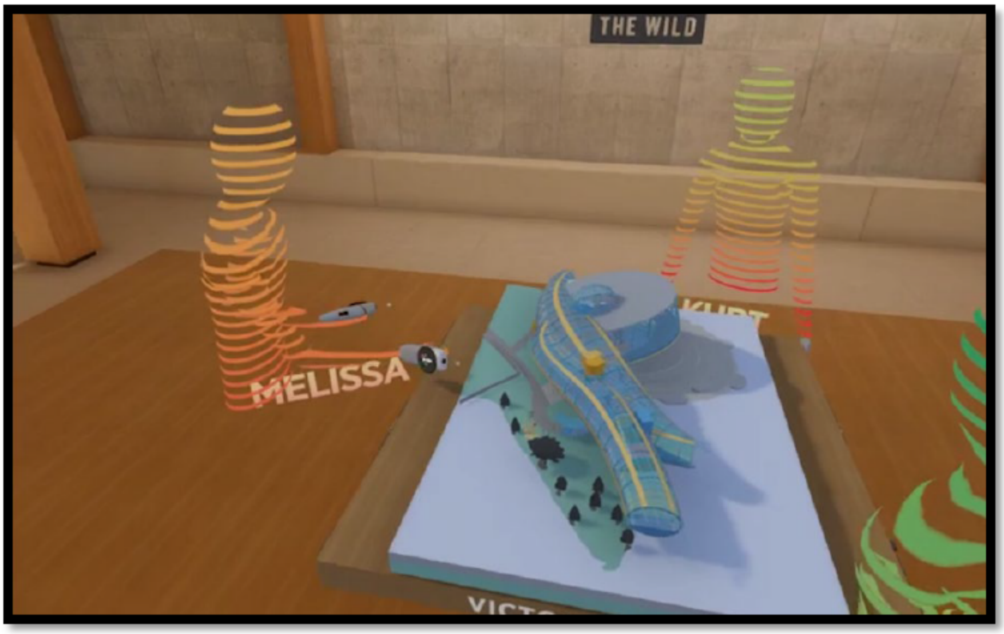

Figure 53. Designing in The Wild (Wild Technology, 2019)

Areas Disrupted

By integrating VR into the design pipeline, designers are finding a vast reduction in the time needed to deliver a concept. *Gravity Sketch* has reported time saving of "up to 60%", with Design Manager at Ford, Michael Smith

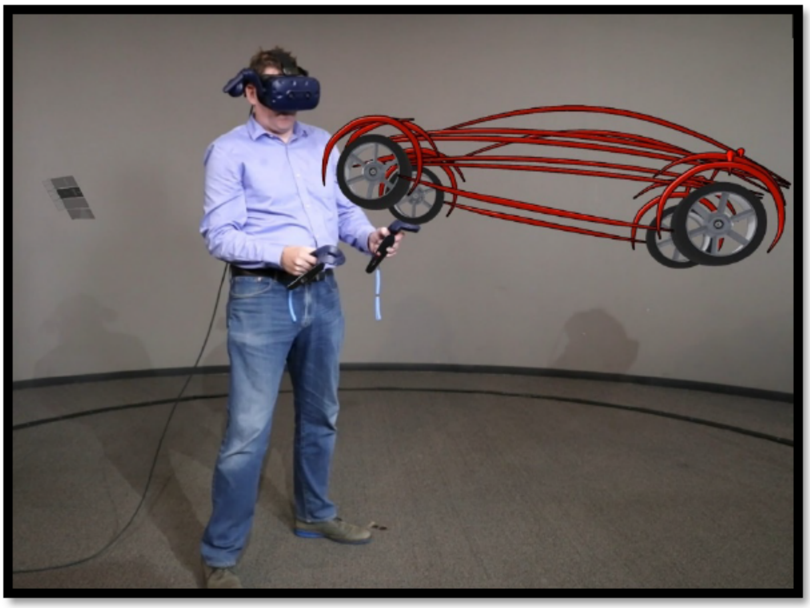

Figure 54. Sketching a Car in Gravity Sketch (A&D, 2019)

stating it "completely changes the way [he approaches] the design process" (Fallon, 2018). He even "skipped a 2D sketch completely" signifying a large shift in design methodology. The abilities provided by a VR design tool are innovating to the point they are helping shift away from traditional parts of the design pipeline such as 2D sketching.

Data has shown that enterprise revenue for VR headsets was set to rise by 69% in 2019, with design being listed as one of the key areas associated with this growth (Taylor, 2019). With such a large boost it is clear that the innovation the technology has is making a monumental shift in the industry. By 2020, it is predicted that thirty-seven million VR headsets will have been used worldwide, with seventy eight percent of Americans now being familiar with the technology (Milijic, 2019). VR is fast becoming a piece of hardware that is unavoidable for most people.

As more and more users turn to VR, there will be less of a need for 2D appliances within the design world such as interactive pens and tablets to draw on screen, as well as a reduced need for physically constructed prototypes and mockups.

As well as disrupting existing technology and pipelines, VR also builds on past experiences offered. New tools can be designed that take advantage of the user being in 3D, such as the ability to stand next to and interact with tracked concepts. For example, a designer can sketch out a motorcycle and then stand over it to see how it appears to the rider. As development increases for these tool sets, more and more useful design practices will become common throughout the industry.

Current and Future Uses

Currently, the software discussed that perform design practices within VR are available for consumer purchase as well as enterprise. Anyone with a VR headset has the opportunity to pick up and design. One of the most popular and breakout applications being Google's *Tilt Brush* (Google, 2016). Launched in

2016, it has seen the creation of many art pieces as well as designs and provided a new platform for creative expression.

The idea of using VR as a tool to immerse can transcend the design world. Similar processes can be repurposed for any background. Teachers can bring artefacts to life for students, scientists can carry out experiments and pilots can fully recreate flights through simulations. A virtual sandbox that can be customised and modified to the operators will is powerful and made possible through the use of technology commonly thought of as simply a method of fun.

One of the main factors preventing the large-scale adoption of VR has been the cost of the hardware. Previously stemming into the thousands of pounds, new headsets such as the *Oculus Quest* make it possible for a full VR setup to be accessible for less than £400 (Facebook Technologies, 2020), a vast reduction in cost that will hopefully increase the ever growing use for designing in VR as well as VR as a whole.

For the product design world, future evolutions require enhanced visuals, better rendering support including Ray Tracing capabilities to create realistic lighting, and simpler importing of data sets. As the performance capabilities of VR increase, so does the output that designers can produce entirely from within the headset. Until standalone headsets are able to have the same level of performance as a computer, there will always be the need for production through a 2D screen. Despite this, VR for design is already happening and if it continues to be adopted it is only a matter of time before it becomes a standard expectation within a designer’s toolkit.

Conclusion

VR for design presents a monumental shift in the way that the process works. Reducing the need for traditional methods such as 2D sketching and replacing this with virtual rooms that people can create within. Platforms have already been established such as *Gravity Sketch, The Wild, Tilt Brush* and various others that showcase the demand for such technological advancement. Each of these present the concept of designing in VR in different ways but all take advantage of building in a virtual space. Concepts are more easily realised when they can be viewed in the exact environment they have been designed for. VR presents the first instance of being able to visualise a product out in the wild without the need to build a physical prototype. Whilst the hardware needs to improve before headsets can fully replace computer workstations, the increasing adoption of VR is a positive step for the design world. When processes can be sped up and made simpler, it makes it easier to reach the end goal of a finished product.

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Appendix A.2: VR for Production

Innovation Title	VR Production	**Available Since**	2016 (Storyboard VR)	**Hardware Options**	HTC Vive, Oculus, Windows MR, Valve Index
Games Technology Utilised	6DoF, Virtual Reality				
Industry Uses	Design, Production, Filmmaking, Pre-Visualisation				

Innovation Overview

Using Virtual Reality (VR) as a method of virtual production that can assist in the development of projects is a new concept that people are beginning to explore. Whether it is in games, television or film, VR can be utilised in a number of ways discussed below that benefit content producers in their day to day challenges. Due to its immersive nature, users can embrace the virtual world of an idea, visualise mood boards, plan out levels or even evaluate imagery from one central device.

A common planning technique, Kanban is a style of approach used to block out ideas allowing for the quick identification of tasks (Corona and Pani, 2013). But what if producers could tie these tasks to the immersive content they are designed to produce? For example, people are now able to plan out entire level designs in VR. Whilst this could be done in a more traditional sense using a pen and paper, by doing it as part of a digital scene allows for interactive content to be inserted at different stages. Perhaps a 360° image appears when physically walking through a plan. Rather than just looking at an image to capture a mood the producer can get a sense of the world by moving amongst an inserted image. Tools such as *Storyboard VR* (Artefact, 2016) provide creators with new ways to block out the ideas in their head and capture the start of something great.

Figure 55. Storyboard VR (Artefact, 2016)

Another example where VR for production boasts a strong ability to innovate is for the evaluation of pre-existing assets. When items have been built digitally in the correct format, the 3D models and other media can be thoroughly explored through a headset. Developers have been working with the *Unreal Engine* (Epic Games, 2020) for a number of years now producing virtual camera tools that allow directors to plan out cinematic sequences by choosing their angles and shot types in real-time. This is a technique already proving useful in industry, with Jon Favreau and his team using a system that does exactly this during production of Disney's *The Lion King* (Technicolor, 2020). Whilst implementing games technology into film may appear uncommon: "some of the most effective tools of storytelling. . . were not even developed by storytellers. They originated in games" (Miller, 2008, p. 70).

By embracing the abilities VR can give creators, there are new ways in which some of the most consumed media in the world can be built. By visualising in new ways and using different methods, there is an opportunity for new concepts to appear out of a VR platform.

Impacts on Design

By isolating users from external distractions and being completely immersed in planning allows users to better visualise tasks. Every single objective can be displayed in front of the producer for them to organise and prioritise. By doing this, the producer can follow some of the key steps of a Kanban process (Al-Baik and Miller, 2014):

1. Visualize workflows
2. Limit work-in-progress
3. Manage flow
4. Make policies explicit
5. Implement feedback loops

Doing this in VR and not following a typical spreadsheet style of approach could make it easier for users to link items together, linking different elements of content and bringing in concept sketches and designs to remind themselves of what tasks need accomplished in which order. Once a production plan has been sketched out in VR others could step in to follow this and provide feedback.

Similarly, design reviews and discussions could be done entirely inside a virtual environment, removing international barriers. Applications such as *AltspaceVR* (Microsoft, 2015) and *MeetinVR* (MeetinVR, 2019) give people the ability to host events and meetings entirely inside a VR headset. People only need to own a headset and be connected to the internet to join in from anywhere in the world, removing many of the main barriers of international projects. *MeetinVR* in particular boasts the ability to explore “3D models, brainstorm, sketch, mind-map, prototype and have team-building activities” all without being physically next to the people you are working with. In 2019, Facebook hosted its annual F8 conference in VR, allowing people to join and watch the keynote speech as one virtual community (Facebook, 2019).

Figure 56. MeetinVR (MeetinVR, 2019)

An ideal design meeting in the future could consist of the host preparing a room as part of the virtual world that contains documentation and 3D models to be reviewed of a particular product. Designers and collaborators would be able to interact with this content and gather around an item to review its features. Feedback would be instantaneous without the need for various email chains going back and forth and this feedback could be captured and noted down by the application for individuals to review at their leisure. Previously, for a design to be properly reviewed a 3D mockup would have to be built with collaborators all travelling to a set meeting place. VR can be used to save time and money which in turn can speed up the design process.

Areas Disrupted

With increased numbers of users inside VR, comes a fundamental shift in the way that people work. It is possible that in the near future every desk will require a VR headset, or potentially people will do without desks entirely as they develop and create in entirely virtual 3D landscapes. Technology is forever changing the world in which we work. One report notes that soon “technology work should evolve to focus on hand-in-hand collaboration with business functions to cocreate value” (Briggs *et al.*, 2019). Whilst technology such as VR and other innovations are already integrating into business, in the near future they may be further relied upon to help drive the next wave of business innovation. The report goes on to discuss how “technology workplaces are evolving from location-centric to relationship-oriented”. The point made here is that ultimately it will not matter where a worker is located, but ultimately how the entire workforce is connected. VR can provide a bridge in this scenario, building international workforces without the need for a physical presence.

Even in industries that traditionally take place on location outside an office environment can be affected by this change. In the TV and film world directors are limited to a certain number of cameras and angles to view a shot from, with TV shows often using three cameras (Bordwell, 2007). By removing this restriction in VR, directors can experiment with as many different cameras and shot types as they wish. When filming a complex sequence, it can be difficult to ensure the footage required is being effectively captured. In the past a technique known as camera angle projection was used to discover what would be recorded (Katz, 1991, p. 16), a process eliminated by viewing cameras in VR. In addition to finding perfect viewpoints, the combination of cameras and lenses chosen will determine the narrative the audience is taken on (Brown *et al.,* 2016). This also has the benefit of allowing lower budget productions to experiment with different camera technology without having to purchase it beforehand.

Despite the monumental shift VR production software can bring about, the areas it is exploring and finding a natural way of progressing, allows many different backgrounds to plan and adjust their daily work routines to allow for better support and organisation going forward.

Current and Future Uses

Currently, VR production is being used all over the world. VR collaboration developers Doghead Simulations created *Rumii* (Doghead Simulations, 2018a) and have demoed the software internationally without having to physically attend many of the events they are showcasing at. Through using VR demonstration, they estimate they have saved over $50 000 in travel costs. Such a vast saving through technology that is as low cost as several hundred pounds is a massive improvement over past methods and one that is likely to increase in uptake in the next few years. In a world increasingly conscious of green initiatives and reducing carbon footprints, VR meeting spaces are likely to be a viable alternative to international travel.

More personal versions of virtual planners include Harvey's room planning AR app (Harveys, 2018) and *Ikea Place* (Ikea, 2017b) an AR app that allows you to position furniture within your own home to see how it would appear before purchasing. In the filmmaking world features such as this can be useful for set decorators and art departments working to quickly visualise a scene as well as the average consumer who simply wants to try out different furniture.

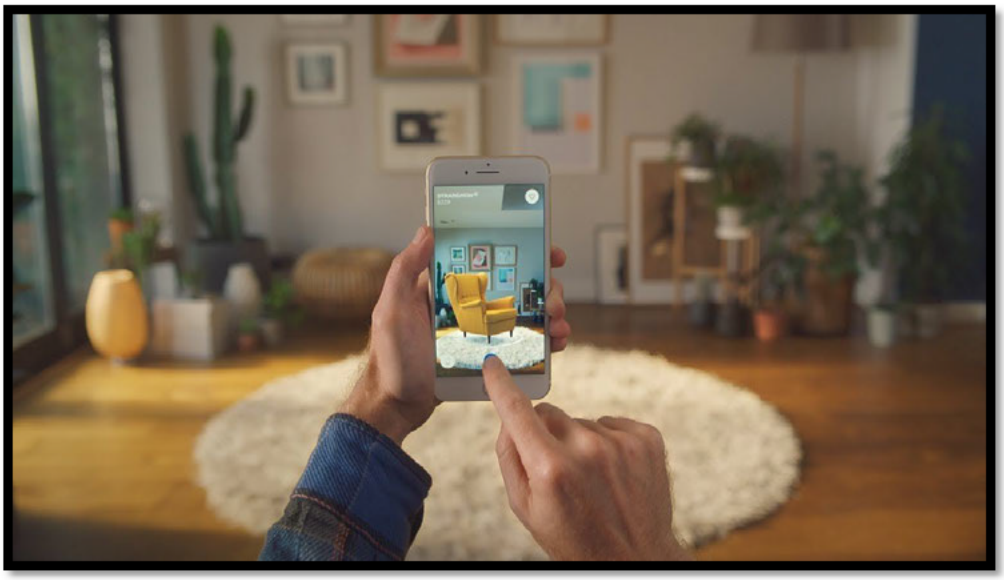

Figure 57. Ikea Place (Ikea, 2017a)

Today, VR is used in many different productions, in particular it has been widely adopted by Disney and their related studios. Both *Rogue One: A Star Wars Story* and *The Mandalorian* have used Unreal Engine technology to visualise content (Cinemablend, 2017) (Jeffrey, 2019). Virtual rendering has become popular in this space as it allows real-time viewing of effects from early planning stages instead of much later down the line (NAÏVE Software, 2019). Instead, directors are using technology from the pre-visualisation stage to assist in the overall production process. As part of this, Epic helped develop a VR tool for stepping into the 3D rendered world and positioning virtual cameras to reflect what the final output of a film or tv show would appear. Other features included the ability to quickly swap out or reposition assets immediately. This makes changing backgrounds and objects in a scene almost instantaneous, removing the need for reshoots at a later date.

With this technology it is entirely possible for a full film or TV show to be developed within VR, allowing crews to quickly get a feel for the finished product.

Conclusion

Virtual Reality is wide ranging in its uses for production, but all of these focus around a common goal: making things easier or more cost effective. The research discussed has explored how an extended use of VR can enable greater product planning, opening up new avenues for feedback and discussion. Producers can choose to lay out an entire project inside VR and link together elements visually for others to follow. Such monumental changes to the way we work have the potential to alter the workplace itself going forward and bring new tools and exciting developments along with it. Being able to review and develop internationally on designs, in the same manner as if everyone was in the same room is a massive advantage. Similarly, other industries such as movie making can harness the power of VR to better create masterpieces through enhanced visualisation tools. Overall, VR is starting to provide various new ways to work and produce projects, all whilst helping the environment and saving time and money for businesses.

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Appendix A.3: AR for Product Development

Innovation Title	AR Product Viewers	**Available Since**	2008 (BMW Ad Campaign)	**Hardware Options**	iPhone, Android Devices, HoloLens, Nreal
Games Technology Utilised	6DoF, Augmented Reality				
Industry Uses	Design, Production, Marketing				

Innovation Overview

Augmented Reality (AR) is a platform that allows digital elements to be represented as part of the real world. Digital assets including 3D geometry can be placed amongst real world environments, through the use of an AR device. In the past few years, the majority of smartphones have gained AR functionality through the use of the cameras on the device. Apple launched their *ARKit* platform in June 2017 (Bajarin, 2017), with Google following shortly thereafter with the Android equivalent, *ARCore*, in March 2018 (Robertson, 2018). Through the technological advances here, a large percentage of the population now have AR capability in everyday life. This gives a wider user reach for being able to share and view digital models at the touch of a button.

Figure 58. AR on Multiple Devices (Underwood, 2020)

AR gives the ability for users to see items that are not physically present in situ amongst an environment. Objects can be placed to scale alongside real-world surroundings. This is an incredibly powerful tool as nowadays products can be viewed before they are manufactured. By blending the digital and physical worlds, people can obtain an understanding of how the product would look at a final endpoint, at a much earlier stage than physical manufacturing.

As part of the design process, a 3D asset will be created which can then be easily dropped into an AR experience for evaluation. Applications such as *Sketchfab* (Sketchfab, 2011) provide quick and easy solutions for building AR content. Once a 3D model has been created, this is then uploaded in a similar fashion to uploading a video to YouTube, with a link then available to share to others.

Recently instant AR viewers have been developed which prevents additional applications having to be installed to experience augmented content (Apple, 2019a). With this addition, AR models can be viewed from a webpage at the press of a button, making the process for sharing AR content far easier than in the past.

Through the utilisation of AR for sharing digital content, products can be showcased in a much more beneficial way, reducing the need for physical mockups and further iterations. The power of AR makes it easy to fully picture a final product throughout the product design pipeline.

Impacts on Design

AR design applications have made their way into the product design pipeline in the past few years with applications such as *Adobe Aero* (Adobe, 2019) and *Vusar* (Vusar, 2019) providing ways to review and explore ongoing work in a quick and convenient format. *Adobe Aero* gives users the ability to take their existing Adobe ecosystem assets and view them in Augmented Reality. There are also animation functions and tools that allow for the fast creation of demos that can then be shared with others. The approach Adobe has taken makes it easy for designers to use the application as they have already created their designs in existing applications and can simply export them for viewing in AR. Similarly, *Vusar* launched with simplicity in mind. The application supports the uploading of various 3D models that can then be easily collaborated with others. This enables people to constantly view the progress of a design in a real-world setting and also to give portability of designs, allowing them to be showcased digitally anywhere in the world. Instead of shipping product prototypes around the world, these applications make it easy to share and view content in a matter of minutes.

Being able to share content easily is one of the main advantages of AR design. In the past few years, the online platform *Sketchfab* has become the go to resource for sharing 3D content. *Sketchfab* allows 3D model files to be uploaded to their site which makes them viewable online. These models can then be shared in the same way as someone would share an online video, simply sending a link to the intended audience. The online platform hosts millions of models (Sketchfab, 2018) and recently introduced an AR mode that can place this content amongst the real world. Applications such as *Sketchfab* are making it a simple process to integrate augmented functionality into the common design pipeline. Due to this, the uptake in AR has become much more plausible with millions of models soon to be instantly available in Apple's *AR Quick Look* thanks to a recent update (Sketchfab, 2020).

Designers are finding AR opens up new possibilities for the development of products. Common tools of a modern AR viewer also offer the ability to easily change colour, scale or even the lighting of objects in real-time to quickly simulate different possibilities before reaching an end result.

Areas Disrupted

The online shopping marketplace has taken advantage of the use of AR with companies such as Ikea (Ikea, 2017) and John Lewis (Sillitoe, 2020) now having virtual catalogues consisting of 3D products. In the past applications would allow for the simple browsing of content and viewing imagery of the product. Now however, features such as John Lewis' *Virtual Sofa* allow items to be positioned in the customer's home. Customers get the chance to see the product and to customise its colour before purchase. It also makes it incredibly easy to compare the wide range of offerings that the store has. AR is a powerful product viewer for the shopping industry as it allows people to see exactly what they're getting and view it in their own home.

AR has also reduced the need for full physical prototypes. In the time it would take a traditional prototype be made, studios are finding that a combination of AR and 3D printing is allowing them to vastly increase the amount of iterations possible in that time. Pivot International (2019) found that "AR-informed 3D-printed prototypes can undergo well over a dozen design iterations in the time required to produce a single prototype using traditional approaches" and similarly Radius Innovation noted that with 3D printing: "a part can undergo 19 design iterations in the time it would take for one iteration using traditional development methods" (Holtorf, 2018) and they expected this to increase even further with the adoption of AR.

AR adoption is also disrupting travel. People can experience products anywhere with the technology. Kipper and Rampolla (2012, p. 136) discuss how Augmented Reality systems will make use of mobile phones developing to a point where they can be used anywhere. Craig (2013, p. 212) agrees with this. He notes that the primary advantage of mobile AR is that "AR applications can be experienced anywhere and at any time".

AR can be seen as a positive disruptor for the future of product development. Reducing geographical restrictions whilst increasing design iterations and being able to create prototypes at a faster rate are just some of the many benefits that AR can bring. In the future this functionality may increase as more use cases are found for this product enhancing technology.

Current and Future Uses

As discussed, AR is primarily a mobile centred technology at this point with the two major players in the industry, Apple and Google, providing toolkits for mobile phones to support augmented functionality. Before this, BMW used people's webcams to demonstrate AR. People could hold up a BMW advert to the camera and see a 3D model of a car appear (Strauss, 2008a). Mentioned previously, ecommerce is one of the main driving forces behind a lot of these experiences, reaping the benefits of the platforms such as ease of use for the consumer. Despite this, Apple have been trying to push the platform to new heights with the addition of AR creation suite *Reality Kit* (Apple, 2019b) and *Reality Composer* (Apple, 2019c). The platforms for Mac and iOS respectively, allow for the development of AR experiences with little to no programming experience. People can insert 3D content, position it in the real world and trigger animations of their choosing. By creating a platform to do this, it opens up the possibility of products to more easily be utilised within AR. Entire presentations can even be planned out in the software before being sent to clients and other end users.

Figure 59. Early BMW AR Demonstration (Strauss, 2008)

Looking to the future of AR, it appears that the mobile experiences that exist currently are paving the way for headset based AR. Devices such as the HoloLens have been around for a number of years but as the technology improves it is more likely we will embrace wearable AR technology. Unveiled in 2015 (Kotaku, 2015), the HoloLens provided a glimpse into a digital future. Whilst using a phone for AR provides convenience, the ability to wear glasses that can display digital content would open up the potential for a true blend of physical and digital world. Other companies such as Nreal (2020) have begun to join the wearable AR world with a device resembling sunglasses that can be worn on the go. Even Google have revisited their *Google Glass* product that never took off many years ago (Google, 2019). Despite not being a true AR headset, it shows the interest in being able to view content in front of your face on the move. It is important to note that in 2007, the smartphone revolution began (Noor, 2016). The prospect of a device that provided a simple to understand interface that could massively benefit everyone's lives was seemingly science fiction at the time. Whereas today everyone carries a smartphone around with them all the time. In a short period of time AR headsets and AR technology in general may be another step towards enhancing human lives.

Conclusion

Augmented Reality has been available to the masses for a number of years now but could still be considered in its infancy. Whilst it has many impressive features including the ability to share content anywhere in the world and view products in situ at the touch of a button, it is yet to fully take off. Once organisations begin to see more of the benefits that industries such as the ecommerce world have seen with the technology, the convenience of AR is likely to grow. The use of AR to fully develop products and present these to others is a use case that many different industries can take advantage of. With a path towards wearable AR and the increasing use of 3D content viewers seemingly likely, the digital and physical words will no doubt blend further in the future to make everyone’s lives more immersive.

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Appendix A.4: Learning Through Games Technology

Innovation Title	Games Tech Learning	Available Since	1967 (Logo Programming)	Hardware Options	Mobile Devices, Tablets, AR/VR Headsets, Laptops, Desktop PC, Mac
Games Technology Utilised	Touch Input, Real-time Rendering, Augmented Reality, Virtual Reality				
Industry Uses	Design, Production, Marketing, Education, Training, Architecture, Engineering, Manufacturing				

Innovation Overview

Although the name games technology would suggest it is only suited to a form of entertainment, games technology provides a way of generating or interacting with content that is unavailable using other methods. Games are a largely visual medium that can be manipulated to present different ideas or engage with various elements. This case study aims to explore how games technology can be utilised to teach and train in a variety of industries. The advantages and disadvantages of this approach will be discussed, alongside some key examples of how games have helped shape the world in the past few decades.

Games technology starts with a game engine. A game engine is a piece of software that combines various pieces of content: 3D models, audio, imagery with a series of scripts that help drive an experience. The two major players in this space are the *Unity* (Unity Technologies, 2018) and *Unreal* (Epic Games, 2020) game engines that provide full support for most types of interactive applications. One of the major advantages of these pieces of software is that they support a range of hardware devices. Through the use of these toolsets during development, experiences can be created and exported to mobile devices, tablets, wearable headsets including Augmented Reality (AR) and Virtual Reality (VR) devices, as well as a standard PC or laptop.

All of these platforms coupled with this technology gives the ability to create content rich, engaging experiences. Instead of focusing solely on an entertainment product, these can be developed to provide a more interactive approach to carrying out tasks or learning new skills. Nowadays entire training courses can be taught through digital app platforms such as *EdApp* (EdApp, 2020). As well as these types of platforms, through the power of immersive content developed for VR headsets, simulating real world or fictional scenarios is also possible. Some of the leading Fortune 500 companies have begun investing in this approach (Liu, 2019), harnessing the power of games technology to better inform their workforce. These are just a handful of the serious games that can be created using game engines and the medium can be applied to all industries through a variety of use cases. In the design world, this increasingly interactive approach is providing designers new ways to build concepts and tackle design challenges, several of which are discussed in the following sections.

Impacts on Design

The design world embraces games technology daily, with common feature sets or experiences built in games software being released with designers at the heart of their intended user base. In 2007, the iPod Touch and iPhone were released (Apple, 2007) and with these came the ability to use touch input directly on a device’s screen. Soon after this, applications took advantage of this form of input, giving users the ability to draw on the display. This soon made it easy to sketch out ideas on the go, giving designers an optimal method for storing their creative ideas quickly. This concept provided such an impact that today the functionality is built in by default to the operating system (Mayo, 2015). When typing notes on an Apple device, users can quickly drop in a sketch they have drawn on screen for use as a quick reminder of an idea, or the outline of a plan.

The use of simulation that games can provide has also found its way into other mediums. Games such as *Farming Simulator* (Giants Software, 2018) and *Train Simulator* (Dovetail Games, 2020), amongst others, have proven highly popular and been around for a number of years. Nowadays there are also full flight simulator setups with dedicated control rigs that offer the ability to replicate flying an aircraft using games technology. Expanding on this are platforms such as *Strivr* that provide immersive experiences to enhance worker training and other avenues such as sports development (Strivr, 2019). *Strivr* provide a selection of VR experiences that allow people to not only train in VR, but also to track analytics through non-invasive methods e.g. they can capture user attention data by placing people in front of a shelf in a supermarket and identifying the products that people are drawn to by knowing what the headset is looking at (Strivr, 2020). This information can then be fed back to design teams who can identify strategies for packaging and conveying information to consumers.

Finally, experiences such as *Vuforia Chalk* (PTC, 2017) and *Dynamics 365 Remote Assist* (Microsoft, 2018) have taken the approach of overlaying helpful information on an AR display. People can examine a situation remotely and provide notes or diagrams drawn on top of the real-world objects. Through this method people can be shown how to operate complex machinery through step-by-step training or be able to get help from anywhere in the world on how to handle a task. They also open up further collaborative design techniques. As these technologies develop further, their benefits to end users will increase even further, particularly as often the developers of these platforms provide software development kits to build upon existing applications (Microsoft, 2019).

Areas Disrupted

Although digital experiences have vast benefits for a whole host of industries, physical training is being phased out as a result. Physical textbooks and revision materials are replaced with educational games and more interactive learning methods. For example, the driving theory test taken in many countries used to be treated as a standard exam which required studying a handbook. Nowadays there are many different theory test applications available on mobile devices (Google, 2020). Applications such as the *Official DVSA Theory Test Kit* (TSO, 2014) make it easy to cycle through exam questions and record scores. This makes it much more beneficial for spotting improvements through study as user's can see their score improve over time. In the UK, even the test itself features elements of games technology. The hazard perception section asks users to highlight on screen potential problem areas, testing the user's responses (DVSA, 2018).

Interactive training is a rapidly growing industry. A simple search on the Apple App Store for training games returns vast results. Training helps sharpen experience. Games can be made that give people the option to do a task over and over again without real world implications. The failure rate for carrying out a task reduces vastly through increasing user experience according to research (Bowers and Bowers, 2010). The research notes that this is due to learners "gaining something from experience that their initial grasp of the basic information didn't equip them to do". Based on this logic we can see that applications to teach skills are a useful tool that games hardware and software enable. Games can help retain knowledge, giving a new way to learn from past methods. In 2011, a virtual environment of a submarine was used to train submariners on the location of safety equipment on board. Users would be able to digitally locate protective equipment and fire extinguishers before stepping foot on the submarine. Over an 18-month period, there was "significant improvement in the real-world performance of the guys who got the software" (Cressey, 2011).

Interactive training and immersive virtual environments are being utilised more and more as noted above. With further innovation and development of hardware in the future, it is likely the use of games technology in other fields is only going to grow going forward.

Current and Future Uses

Today there are numerous devices and platforms all designed to enhance learning for consumers and employees. An early example of this was in 1967, when *Logo* (BBN Technologies, 1967) provided a fun way to teach programming concepts to children. Despite being a programming language itself, it taught users how to create simple shapes through programming in an entertaining way. Several years later *The Oregon Trail* (Minnesota Educational Computing Consortium, 1974) helped teach history to school children. Nowadays educational content has progressed in big ways. Over one million iPads are now in use at schools in the United States (Meaney, 2017) with experiences such as *Minecraft Education Edition* (Mojang, 2020a) providing new ways to teach subjects such as maths, art and science. Lesson plans and virtual worlds created to depict geographical locations help teach the curriculum in over one hundred countries (Mojang, 2020b). Even the U.S. Army has witnessed the power of games and in 2002 released their own game *America's Army* (United States Army, 2002) designed to encourage young adults to join the military. Although ethically questionable, others find: "the fact that video games can interest youth in violence, train them in tactics, and potentially disinhibit aggressive behaviours is a positive effect" (Anderson, Buckley and Gentile, 2007).

Using games as a learning experience could be considered beneficial by all. In a study into educators and players thoughts on learning through games, there was unanimous agreement that they could be used for learning development (Dagnino *et al.,* 2019). Whilst there was a dispute over the best use of games for teaching, all participants saw their potential as a training medium. Mitchell (2012, p. 39) notes that businesses have "embraced gaming as an approach to training methods for all kinds of jobs, from accountants to surgeons to human resource managers and so on" describing it as "big business" in the world of work. Gamified learning today has expanded from classroom experiences to the entire global workforce.

Even game engines today have built in support for creating these types of experiences. Both *Unity* and the *Unreal Engine* have enormous feature sets that can be manipulated to better assist learning. Features such as: audio support, physics, 3D models, coordinate systems, scripted events and many more. This list continues to grow. In 2020, *Unity* plans to introduce visual scripting and enhanced animation which again could be used to build new and improved training platforms (Thacker, 2019).

With the continued growth of games technology in learning, games are likely to continue being developed that help expand knowledge and increase productivity of workers in the future.

Conclusion

Learning through games technology has been shown to be an effective tool for engaging the masses in training and acquiring new skills. With the range of digital solutions now available across big business, it is likely at some point that most workers will encounter a form of game as part of a training program. With the vast array of hardware solutions now available there are different options that suit different training needs. Whether it is educating children using an iPad or using immersive VR headsets to track people's subtle movements, games technology can help. With the ever-expanding toolsets on offer from development platforms games technology appears here to stay with increasing use and expansion seeming inevitable in the 21st century.

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Appendix B – DiGRA 2020 Extended Abstract

Appendix B.1: Build Through Play: How Engaging Mechanics Benefit Productivity

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creativity, mechanics, productivity, tools

ABSTRACT
Sandbox and educational games are often developed with a similar approach. In both, the game mechanics must be engaging to maintain player interest. However, when giving the player the freedom to do as they please, there must still be constraints to the experience. Some of the most successful serious games that have been utilised in education and training found their success in straight forward, intuitive and most importantly fun mechanics for players. Games such as *Minecraft* (Mojang 2009) have helped enhance education by showing that when users are given enjoyment as part of their learning, they can be taught complex concepts and design incredible creations (Levin 2016). This abstract explores the hypothesis that providing an engaging toolset that people enjoy using, increases the user's ability to create. The research outlined will explore various in-game toolsets that encourage the player to be productive and to generate content, whilst still providing an entertaining experience. Finally, this study will explore the notion of 'fun' improving performance, taking examples from the games discussed and a prototype built as part of this research.

Individuals both in the real world and in game worlds perform similar tasks. Building ideas, constructing items and planning events being key examples of everyday life that have been represented in digital counterparts. Over the years there have been various attempts to make such tasks simpler whilst furthering their entertainment value. Thus, making it less of a chore for those carrying out the tasks to achieve their goal. As part of this research, a closer examination was undertaken at how game mechanics help increase a player's creative output. Three popular examples of designing through play have been chosen from popular games on the market.

Game mechanics have the ability to "play a significant role in improving users' concentration and enjoyment" (Wang et al. 2017). To retain a player's interest, game mechanics need to engage players in accomplishing the game's goals. Kalinauskas (2014) discusses how mechanics can position people into a "*flow*", manipulating their self-determination in order to accomplish a task. When this is applied to a game that encourages player expression and creativity, no matter the result, users are determined to generate ideas as they complete the game. This idea of being encouraged to complete something entices the player to press onwards and succeed. When challenges arise, the player has a goal, making them more motivated to obtain success.

Games also allow people to apply their knowledge in a constructive manner, generating outputs as a direct result of their own inputs of knowledge. Serious games have been utilised to do this for decades by military personnel as part of a *"combination of war games, computer sciences, and operations research"*. Another group benefiting from their use are engineering students, with serious games "*[showing] a positive effect on the students' abilities to apply the theoretical gained knowledge*" they have obtained (Hauge et al. 2013).

By building an experience that allows people to be expressive and making them want to explore, often incredible output is achieved as a result. *Minecraft's* block building mechanics have allowed it to become one of the most widely adopted and impactful educational games of the past decade. To date, over 115 countries have integrated the game as part of classroom teaching (Valentine 2019). *Minecraft's* in-game toolsets have been adopted to explore mathematics, geography, science and art (Abrams 2017). The game even provides its own spin on electronic circuits, helping teach advanced techniques by communicating concepts in an easy to understand manner. Similarly, Forge mode in *Halo 5* (343 Industries 2015) began as a simple level editor in previous editions of the franchise and has grown into what could be considered a game engine in itself. Support for these toolsets within the game's community is vast in numbers, with millions of pieces of user created content generated (Postums 2019). Today's editor allows for scripted events and triggers that allow entire scenarios and sequences to be planned out whilst also providing an insight into games programming. By giving players engaging building mechanics, players to this day are still developing additional custom content for the game. Finally, *Trials Evolution* (RedLynx 2012) featured a level editor that has been utilised to build entirely new games. By doing so, players were able to create content that further pushed the scope of the original experience whilst engaging players in constructing new content. Its sequel *Trials Fusion* (RedLynx 2014) has a marketplace featuring over one hundred and eighty thousand user created tracks (RedLynx 2019), highlighting the widespread appeal of building through play.

People are more willing to carry out work and construct ideas when given a fun environment or context to do it within. Past research suggests "*workplace fun positively relates to employees' job performance*" (Tang et al. 2017), a topic that has been researched in detail over the years. Woolf (2014) further explored this, detailing that "*individuals having fun at work were also more likely to be more engaged in their work, and consequently exhibit greater creative performance*". By applying this concept to other industries there is the chance that more complex challenges can be solved through the entertaining prospect of play. The philosophy behind this has led past researchers to believe play provides meaning and therefore a willingness to accomplish tasks (Rodriguez 2006), with serious games designers able to take advantage of these aspects if they "*exploit and highlight*" the ludic elements of work. Finding fun through necessity provides the user with a more entertaining method of solving complex problems or achieving long standing goals. Game mechanics provide a solution to these complex problems and: "*in good video games, the problems players face are ordered so* *that the earlier ones are well built to lead players to form hypotheses that work well for later, harder problems*" (Gee 2007). Game mechanics build upon past experiences, much alike career progression or the natural order of education.

The ability to build mechanics in a way that benefits productivity is showcased here as a concept explored by games for several years. A key part of this research was applying the discussed philosophy into the development of a VR sketch prototype titled *Reality Works*. Designing in this format provided the ability for more freedom in the creation of 3D designs, making it easier for creators to express their ideas by utilizing mechanics that are fun to develop with.

Level editors, construction mechanics and designing worlds are all features that provide an engaging way for concepts to be explored. The key philosophy behind this research has begun to see this as a reason as to why complex tasks can be more easily conquered as the enjoyment factor plays a large role in people's willingness to solve problems. Further research is underway into the specific mechanics that provide benefits to further define the best way to stimulate productivity using games.

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Appendix C – Ethical Approval

Appendix C.1: Ethical Approval Certificate

Abertay University

Name: JACK GULLEN

Project Title: The Future of Product Design: How Games Technology is Evolving the Design Process

Reference: EMS1833

Status: Full Approval

Approval Date: 03.10.19

The Standard Conditions below apply to all approved Research Ethics applications:

i. If any substantive changes to the proposed project are made, a new ethical approval application must be submitted to the Committee.
In addition, for non-staff projects:
ii. The Proposer must remain in regular contact with the project supervisor.
iii. The Supervisor must see a copy of all materials and procedures prior to commencing data collection.
iv. Any changes to the agreed procedures must be negotiated with the project supervisor.

Figure 60. Ethical Approval Certificate